In Situ Oil Sands
Footprint Monitoring Project

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EXECUTIVE SUMMARY

Stakeholders and regulators have become increasingly concerned about the cumulative impact of existing and future in situ oil sands operations on ecosystem health and reclamation success in the Lakeland Industrial and Community Association (LICA) region. To respond to these concerns, Alberta Environment (AENV) commissioned a pilot project to develop a terrestrial footprint monitoring protocol for the LICA region. The In situ Footprint Monitoring Project (the In situ project) was completed by the ALCES Group in association with InfoJim Inc. The intent of the project was to establish a foundation for ongoing monitoring of the in situ development footprint that would ultimately assist stakeholders and regulators in responsible land management and sustainable development. Specific objectives defined by AENV were:

1. Develop an indicator-based approach and protocol to assess landscape features and evaluate land disturbances and reclamation progress over time, utilizing spatial information at an appropriate scale to enable comprehensive evaluation of cumulative land disturbances.
2. Using the developed protocol – identify, monitor, and map the cumulative land footprint associated with in situ activities for the selected area between 1980 and 2007, and to enable periodic updates after 2007.

Indicator-Based Monitoring Protocol

A long-term monitoring program using an indicator-based protocol and existing, readily available data is the most practical and cost-effective method to document changes in the cumulative terrestrial footprint over time at a regional to provincial scale.

For the In situ project, a suite of eight generalized disturbance and reclamation indicators was adopted. As described in Section 2, the selected indicators:

- allow the effects of both in situ and combined footprints to be evaluated and differentiated;
- support existing management and decision making structures;
- are practical to implement; and
- are scientifically defensible.

Four disturbance indicators (Land Use Footprint, Corridor Density, Riparian Footprint, and Core Area) were selected to provide information about combined direct and indirect land use footprints. These disturbance indicators can be used to evaluate terrestrial and aquatic cumulative effects risks and associated risks to achieving desired provincial, regional, and sub-regional ecological and social outcomes.

Three reclamation indicators (Certified Footprint, Inactive Footprint, and Restored Footprint) were selected to quantify how much footprint has been or could be reclaimed as well as its reclamation status relative to natural (pre-disturbance) landscape conditions.

Finally, one combined disturbance and reclamation indicator (Net Footprint) was selected to provide a simple measure of combined footprint less the area that has been restored to natural conditions (i.e., Net Footprint = Land Use Footprint – Restored Footprint).

In addition to focusing landscape disturbance monitoring over time, these landscape indicators can also be applied to provide clear, measurable disturbance or reclamation thresholds. These thresholds would be set to achieve desired regional or provincial outcomes (e.g., Net Footprint not to exceed X% to protect social and ecological values). With this approach, landscape indicator monitoring would also allow land managers and users to document status relative to these pre-defined management objectives.

To demonstrate the indicator-based monitoring protocol within the LICA region, a National Topographic System 1:50 000 map sheet (73L10) was selected as the project area. Indicator values were calculated for the entire project area, as well as several smaller study areas (two natural subregions, two watersheds, and four complete and eight partial townships) to illustrate how footprint monitoring can simultaneously be related to mapping boundaries, terrestrial ecological boundaries, aquatic ecological boundaries, and administrative boundaries. A Geographic Information System was used to map historical and current land use footprints and prepare data for analysis. MS Access® (Microsoft Office 2007) was used to complete the analyses of all indicators.

The protocol steps required to create datasets for calculating each indicator are provided in Section 3 this report along with details relating to the application of each step to the In situ project area.

Conclusions and Recommendations

In general, the disturbance indicators showed increasing trends from 1981 to the current time period (Land Use Footprint – 12.3% to 18.5% of the project area; Corridor Density – median of 1.1 km/km^2 to 2.7 km/km^2, Riparian Footprint – 2.7% to 6.2% of riparian habitat) with a corresponding decrease in Core Area (47% to 17% of the project area). A relatively small proportion of the In situ project area (0.07%) appears to have been reclaimed. Based on scientific literature, the risk of adverse cumulative effects on boreal forest ecosystem function has substantially increased because of the cumulative footprint and landscape fragmentation since 1981.

Accurate, timely, and accessible information is essential for footprint monitoring. The use of readily available data in the In situ project highlighted existing data and reporting deficiencies. During development and application of the In situ footprint monitoring protocol, the primary constraint was the lack of consistent, attributed, geo-referenced and up-to-date land use and reclamation data. This is a result of several factors:

- Surface allocations / disturbances and reclamation status are tracked by independent government ministries, agencies, and proponents.
- The apparent lack of a spatially explicit record of well lease footprints present on the land base created a huge data gap in understanding the cumulative effects of hydrocarbon development in the LICA region and elsewhere.

- ASRD base features data, as a whole, are updated on an ongoing basis using aerial photography and satellite imagery, however, not all feature types or areas are updated every year and any one feature type or particular area may not be updated for several years, as in the In situ project, where the much of the data in the project area were last updated in approximately 2001.
- Reclamation status information is deficient for most land use features, and a reasonable estimate of Net Footprint could not be developed.

The following recommendations address data and analysis inadequacies identified during the In situ project as well as suggestions for monitoring protocol implementation by AENV.

1. Implement consistent cross-ministry as-built reporting of land use footprints, including geo-referenced data on feature location, type, size, age, and activity status according to prescribed standards. The Information Management system proposed in the draft Land Use Framework (ASRD 2008) may be an appropriate vehicle to coordinate this.

2. Improve and expand the existing ASRD base features update system to include all anthropogenic surface disturbances (e.g., well sites, small oil and gas facilities, borrow pits) thus consolidating the land use footprint mapping within the base features mapping process, and increase update frequency in areas of intensive resource development.

3. Require reclamation objectives and vegetation status to be included as attributes in digital land use data for all land uses and as part of Conservation and Reclamation reporting. Conservation and Reclamation data should be digital, geo-referenced, and should document:
   - actual footprint location, size, and status (i.e., Active, Inactive);
   - reclamation objectives (i.e., Natural Reclamation to Wetland, Natural Reclamation to Grassland, Natural Reclamation to Forest, Crop and Forage Land, Equivalent Ecological Function, or other agreed-upon objective); and
   - reclamation status relative to objectives (i.e., Restored; Not Yet Restored; Certified) and related to site-specific soil, vegetation, and landscape monitoring data specified by AENV criteria (1995; 2007b).

   Additional requirements for Conservation and Reclamation reports:
   - annual or regular updates to monitor changes in footprint indicators and reclamation status
   - summaries that document footprint indicator status for their activities, namely Land Use Footprint, Corridor Density, Core Area, Riparian Area Disturbed, Certified Footprint, Inactive Footprint, Restored Footprint, and Net Footprint.

4. Systematically implement the protocol to document landscape conditions throughout LICA and other parts of the province.

5. Develop regional disturbance or reclamation targets for the landscape indicators in the LICA region as part of the Land Use Framework - Northeast Alberta Regional Plan initiative. These management targets should be designed to achieve desired regional or provincial social, ecological, and economic outcomes and should be developed with input from regulatory agencies, land users, and the general public.

TABLE OF CONTENTS

Executive Summary i
Table of Contents v
List of Figures vi
List of Tables vii
Glossary viii

1. INTRODUCTION 1
1.1 Report Format 1
1.2 Footprint Indicator Background 2
1.2.1 Landscapes and Habitat 2
1.2.2 Selecting Indicators 7
1.2.3 Alberta Monitoring Initiatives 8
Land Monitoring Review 9
Land Use Framework Monitoring and Evaluation 10
State of the Environment Reporting 10
Biodiversity Initiatives 11
Cumulative Effects Management Association 11

2. IN SITU FOOTPRINT MONITORING INDICATORS 12
2.1 Selection Criteria 12
2.1.1 Support Existing Management and Decision-making 12
2.1.2 Practical to Apply 13
2.1.3 Scientifically Defensible 13
2.2 Recommended Indicator Overview 14
2.2.1 Land Use Footprint (Cleared/Disturbed Area) 16
Rationale 16
2.2.2 Corridor Density 17
Rationale 17
2.2.3 Riparian Footprint (Riparian Disturbance) 18
Rationale 18
2.2.4 Core Area 19
Rationale 20
2.2.5 Certified Footprint 20
Rationale 21
2.2.6 Inactive Footprint 21
Rationale 22
2.2.7 Restored Footprint 22
Rationale 22
2.2.8 Net Footprint 23

3. INDICATOR MONITORING PROTOCOL 24
3.1 Project and Study Area Selection 24
3.2 Data Acquisition and Analysis 27
3.2.1 Data Acquisition - Current Time Period 27
3.2.2 Data Acquisition - Historical Time Period 29
3.2.3 Data Analysis 29
3.3 Indicator Analysis 29
3.3.1 Land Use Footprint 29
3.3.2 Corridor Density 40
3.3.3 Riparian Footprint (Riparian Disturbance) 49

3.3.4 Core Area 55
3.3.5 Certified Footprint 60
3.3.6 Inactive Footprint 64
3.3.7 Restored Footprint 65
3.3.8 Net Footprint 67

4. CONCLUSIONS AND RECOMMENDATIONS 68
4.1 Findings 68
4.2 Issues and Recommendations 73

5. REFERENCES 76
5.1 Personal Communication 76
5.2 Literature Cited 76

APPENDIX A. Land Use Footprint Type Classification Scheme for ASRD Access Base Feature and AVI Data.
APPENDIX B. Footprint Indicator Results for all Study Areas within the 73L.10 Project Area.

LIST OF FIGURES

Figure 1. Lakeland Industrial and Community Association region 3
Figure 2. Elements of a forest landscape 4
Figure 3. Elements of an agricultural landscape 4
Figure 4. Relationship between patch size and edge area (the indirect footprint) assuming 50 m edge width (adapted from Collinge 1996) 6
Figure 5. Relationship between patch geometry and edge area assuming 50 m edge width (adapted from Collinge 1996) 6
Figure 6. The riparian zone adjacent to waterbodies 18
Figure 7. Core area remaining beyond direct and indirect footprint; area A represents patch with no remaining core habitat (Temple 1984) 19
Figure 8. Study area boundaries for the In situ project area (73L10) 26
Figure 9. Current Land Use Footprint for the In situ project area (73L10) 38
Figure 10. Historical Land Use Footprint for the In situ project area (73L10) 39
Figure 11. Example of boundary effects 42
Figure 12. Current Corridor Density for the In situ project area (73L10) 47
Figure 13. Historical Corridor Density for the In situ project area (73L10) 48
Figure 14. Current Riparian Footprint for the In situ project area (73L10) 53
Figure 15. Historical Riparian Footprint for the In situ project area (73L10) 54
Figure 16. Current Core Area results for the In situ project area (73L10) 58
Figure 17. Historical Core Area result for the In situ project area (73L10) 59
Figure 18. Current Certified and Inactive Footprint Results for the In Situ Project Area (73L10) 62
Figure 19. Historical Certified Footprint Results for the In Situ Project Area (73L10) 63
Figure 20. Change in Land Use Footprint since 1981 in comparison to example risk ratings provided in Section 2.2.1 71
Figure 21. Change in Corridor Density since 1981 in comparison to example risk ratings provided in Section 2.2.2 71

Figure 22. Change in Riparian Footprint since 1981 in comparison to example risk ratings provided in Section 2.2.3. ... 72
Figure 23. Change in Core Area since 1981 in comparison to example risk ratings provided in Section 2.2.4. ... 72

LIST OF TABLES

Table 1. Recommended in situ oil sands footprint monitoring indicators. ... 15
Table 2. Land use footprints and data sources for the In situ footprint monitoring pilot project study area (current time period). ... 28
Table 3. Land Use Footprint indicator analysis steps. ... 30
Table 4. Size and hierarchy of land use footprint types. ... 34
Table 5. Example subregional (terrestrial, aquatic, and administrative) Land Use Footprint analyses for the current (~2001) and historical (1981) time periods. ... 37
Table 6. Corridor Density indicator analysis steps. ... 40
Table 7. Comparison of Corridor Density analyses using different methods to account for partial block data. ... 45
Table 8. Example subregional (terrestrial, aquatic, and administrative) Corridor Density analyses for the current (~2001) and historical (1981) time periods. ... 46
Table 9. Riparian Footprint indicator analysis steps. ... 49
Table 10. Example subregional (terrestrial, aquatic, and administrative) Riparian Footprint analyses for the current (~2001) and historical (1981) time periods. ... 52
Table 11. Core Area indicator analysis steps. ... 55
Table 12. Example subregional (terrestrial, aquatic, and administrative) Core Area analyses for the current (~2001) and historical (1981) time periods. ... 57
Table 13. Certified Footprint indicator analysis steps. ... 60
Table 14. Example subregional (terrestrial, aquatic, and administrative) Certified Footprint analyses for the current (~2001) time period. ... 64
Table 15. Inactive Footprint indicator analysis steps. ... 64
Table 16. Example subregional (terrestrial, aquatic, and administrative) inactive footprint analyses for the current (~2001) time period. ... 65
Table 17. Restored Footprint indicator analysis steps. ... 66
Table 18. Net Footprint indicator analysis steps. ... 67
Table 19. Terrestrial and aquatic cumulative effect indicators for the In situ project area,73L10 – historical (1981) time period. ... 69
Table 20. Terrestrial and aquatic cumulative effect indicators for the In situ project area, 73L10 – current (~2001) time period. ... 70

GLOSSARY

Agricultural landscape - human-dominated landscape composed of agricultural land with remnant areas of native trees, shrubs, and grasses in patches and along corridors (e.g., windrows or along road ditches).

Certified footprint - proportion of study area for which Reclamation Certificates have been issued, but ecological function has been affected (i.e., non-native or incompatible vegetation community established).

Clip - a geometric process that separates out features from one feature class that reside entirely within a boundary defined by features in the 'clipping' feature class.

Core area – an area with minimal human impacts. Core areas are relatively undisturbed, 'unroaded' areas; they are often source areas for plant and animal populations or metapopulations.

Corridor – a reasonably uniform, linear feature that differs from its surrounding landscape. Corridors can occur naturally (e.g., river valley, windrow, aeolian ridge) or as a result of human disturbance (e.g., roads, cutlines).

Corridor density - average density of all linear corridors within the study area (km corridors/km^2).

Cumulative effects – unexpected or unintended effects resulting from independent activities or land uses.

Current time period or landscape - for the purposed of the In situ project, the current time period is based on the currency of the data used, approximately between 2001 and 2005.

Direct footprint - refers to the area where the land surface is physically disturbed.

Dissolve – a geoprocessing command for removing boundaries between adjacent polygons that have the same values for a specified attribute/field.

Ecological function – equals ecological integrity.

Feature class - Feature classes are homogeneous collections of common features, each having the same spatial representation, such as points, lines, or polygons, and a common set of attribute columns, for example, a line feature class for representing road centerlines. (ESRI, 2008)

Field - a column in a table that stores the values for a single attribute – the table is associated to a layer in the GIS.

Forest landscape – a landscape composed of treed patches of variable size, age, structure, and species composition, unforested natural openings associated with waterbodies, wetlands, and low-growing vegetative cover, and human-disturbed patches such as well sites and cut blocks, as well as disturbance corridors like roads, trails, and power line and pipeline rights-of-way.

Geographic Information System (GIS) - a system designed to allow users to collect, manage, and analyze large volumes of spatially referenced and associated attribute data.

Habitat alteration – habitat alteration occurs with disturbance of original habitat. *Temporary habitat alteration* occurs when pre-disturbance conditions are allowed to re-establish (e.g., forest re-growth after harvest). *Permanent terrestrial habitat alteration* occurs when different vegetation becomes established on the disturbed area (e.g., converting mixedwood forest to domestic grasses for hay production, introducing non-native species). *Permanent aquatic habitat alteration* occurs when substrate or channel conditions are modified, or where flow and sediment transport patterns are modified by upstream activities.

Habitat effectiveness – habitat quality, as perceived by a particular species. For instance, when a species uses the area around a man-made facility less than nearby areas of identical habitat, there has been a decrease in habitat effectiveness.

Habitat loss – loss of habitat can occur in either terrestrial or aquatic ecosystems. *Terrestrial habitat loss* occurs when human activities disturb the soil or remove vegetation and re-growth is not allowed to occur (e.g., construction of a city, highway, or industrial facility). *Aquatic habitat loss* occurs when water is removed, chemistry is substantially altered, or the structure of the waterbody is substantially altered.

Historical time period or landscape – for the purpose of the In situ project, the historical time period is dated 1981.

Home range - the area used by an animal for food, shelter, and reproduction.

Inactive footprint - proportion of study area where native vegetation or natural ground cover has been cleared or disturbed and land use has been discontinued, Reclamation Certificate has not been issued, and ecological function has been affected.

Index – a numerical value used to represent or monitor the condition of an abiotic or biotic resource.

Indicator - a characteristic of the biophysical, ecological, or social setting that is used to describe, measure, manage, and report on resources of interest.

Indirect footprint - refers to the area adjacent to the direct footprint where plants, animals, and people are influenced by the physical disturbance of the footprint or by ongoing activities on the footprint.

Intersect – a geometric integration of spatial datasets that preserves features or portions of features that fall within areas common to the input datasets.

Land use footprint - proportion of study area where native vegetation or natural ground cover has been cleared or disturbed and ecological function has been affected.

Landscape - an area of tens to hundreds of square kilometers that includes one dominant background ecosystem. The LICA region includes forest, agricultural, and urban landscapes.

Layer - the visual representation of a geographic dataset in any digital map environment. On a road map, for example, roads, national parks, political boundaries, and rivers might be considered different layers.

Line - on a map, a geometric element defined by a connected series of unique x,y coordinate pairs. A line has length, may be straight or curved, but does not have an area.

Matrix – a dominant background ecosystem or land-use type within a habitat mosaic. Within the matrix, patches and corridors are reasonably uniform areas and linear features that differ from their surroundings.

Merge – a geoprocessing term for combining features from multiple data sources of the same data type (i.e., geometry) into a single, new dataset.

Mosaic – in an ecological context, mosaic refers to a pattern comprised of three basic units: patches, corridors, and the matrix.

Net footprint - proportion of study area where native vegetation or natural ground cover has been cleared or disturbed less Restored Footprint (i.e., ecological function has been affected).

Orthorectified - orthorectification converts imagery into map-accurate forms by accurately removing sensor and terrain-related distortions from raw imagery.

Patch – a reasonably uniform area that differs from its surrounding landscape. Patches occur naturally (e.g., sloughs, burns) or as a result of human disturbance (e.g., farmyards, wellsites, clearcuts).

Point - a geometric element defined by a single pair of x, y coordinates; it is a map feature that has neither length nor area.

Polygon - a mapping term used to describe a closed geometric entity that has an area, and is defined by a connected sequence of x,y coordinate pairs, where the first and last coordinate pair are the same and all other pairs are unique.

Project area – the 1:50,000 73L10 map sheet footprint analysis unit selected for the In situ Footprint Monitoring project.

Residual core area – . area with minimal human impacts (see core area).

Riparian zone – wetland complexes and land adjacent to a waterbody where the seasonal water table influences soil and vegetation.

Riparian footprint or riparian disturbance - proportion of riparian/wetland area where native vegetation or natural ground cover has been cleared or disturbed and ecological function has been affected.

Region – in an ecological context, region refers to an area more than hundreds of square kilometers that incorporates several landscapes.

Restored footprint - proportion of study area for which Reclamation Certificate has been issued (where required) and ecological function has been restored (i.e., self-sustaining compatible native vegetation community has been established) for at least 10 years.

Study area - footprint analysis subunits within the project area, including Natural Subregions, watersheds, and townships.

Union - a geoprocessing term for overlaying two or more polygon spatial datasets that preserves the features that fall within the spatial extent of either input dataset; that is, all features from both datasets are retained and merged into a new polygon dataset.

Zone of influence – the distance to which a species' behaviour is affected by an activity or land use feature.

1. INTRODUCTION

In situ oil sands development consists of networks of infrastructure and transportation corridors and facilities that extract deep, unmineable bitumen. The primary in situ extraction technique is the Steam Assisted Gravity Drain (SAGD) process. This uses high pressure steam to liquefy the tar-like oil sands deposits so that they can be piped to the surface. Supporting exploration and production infrastructure includes: seismic lines, well pads, central processing facility(s), above ground interconnecting pipeline system, access roads, and power lines (Axys *et al.* 1997; Blackrock 2001, Husky 2003).

Stakeholders and regulators have become increasingly concerned about the cumulative impact of this type of development on land resources in the Lakeland Industrial and Community Association (LICA) region (Figure 1). Concern is largely focused on impacts of existing and future oil sands operations on ecosystem health and reclamation success. In "Death by a Thousand Cuts" (Schneider and Dyer 2006) it is predicted that in situ oil sands operations could occupy up to 138,000 km^2 or 21% of Alberta resulting in 11,454 km^2 of cleared boreal forest and 441,600 km of roads. The report claims that reclamation efforts will not restore the boreal forest and continued development is at ecologically unsustainable levels. To respond to these concerns, Alberta Environment (AENV) commissioned a pilot project to develop a terrestrial footprint monitoring protocol for the LICA region.

The In situ Footprint Monitoring Project (the In situ project) was completed by the ALCES® Group in association with InfoJim Inc. The intent of the project was to establish a foundation for ongoing monitoring of the in situ development footprint that would ultimately assist stakeholders and regulators in responsible land management and sustainable development. Specific objectives defined by AENV were:

1. Develop an indicator-based approach and protocol to assess landscape features and evaluate land disturbances and reclamation progress over time, utilizing spatial information at an appropriate scale to enable comprehensive evaluation of cumulative land disturbances.
2. Using the developed protocol – identify, monitor, and map the cumulative land footprint associated with in situ activities for the selected area between 1980 and 2007, and to enable periodic updates after 2007.

1.1 REPORT FORMAT

Section 1.2 of this report provides a discussion of landscape ecology as it relates to monitoring indicators as well as a review of indicators currently used in Alberta by various regulatory initiatives. Recommended monitoring indicators for the In situ project are described in Section 2. Section 3 summarizes the data acquisition and analysis protocol and details the steps to be followed to document the historical or current status of each indicator. This section also references examples of the analyses conducted for this project. The results of applying this protocol to the In situ project area then are provided in Section 4, along with conclusions and recommendations for ongoing footprint monitoring in the LICA region and other areas of Alberta. Appendix A presents the classification scheme used for the project; complete indicator analysis results for the In situ project area are included in Appendix B.

1.2 FOOTPRINT INDICATOR BACKGROUND

The following information on landscape ecology (Section 1.2.1), landscape indicators (Section 1.2.2) and monitoring indicators used in other provincial initiatives (Section 1.2.3) is provided as background. These concepts and initiatives were considered when selecting the recommended in situ indicators described in Section 2. Readers familiar with landscape ecology and monitoring initiatives should proceed directly to Section 2.

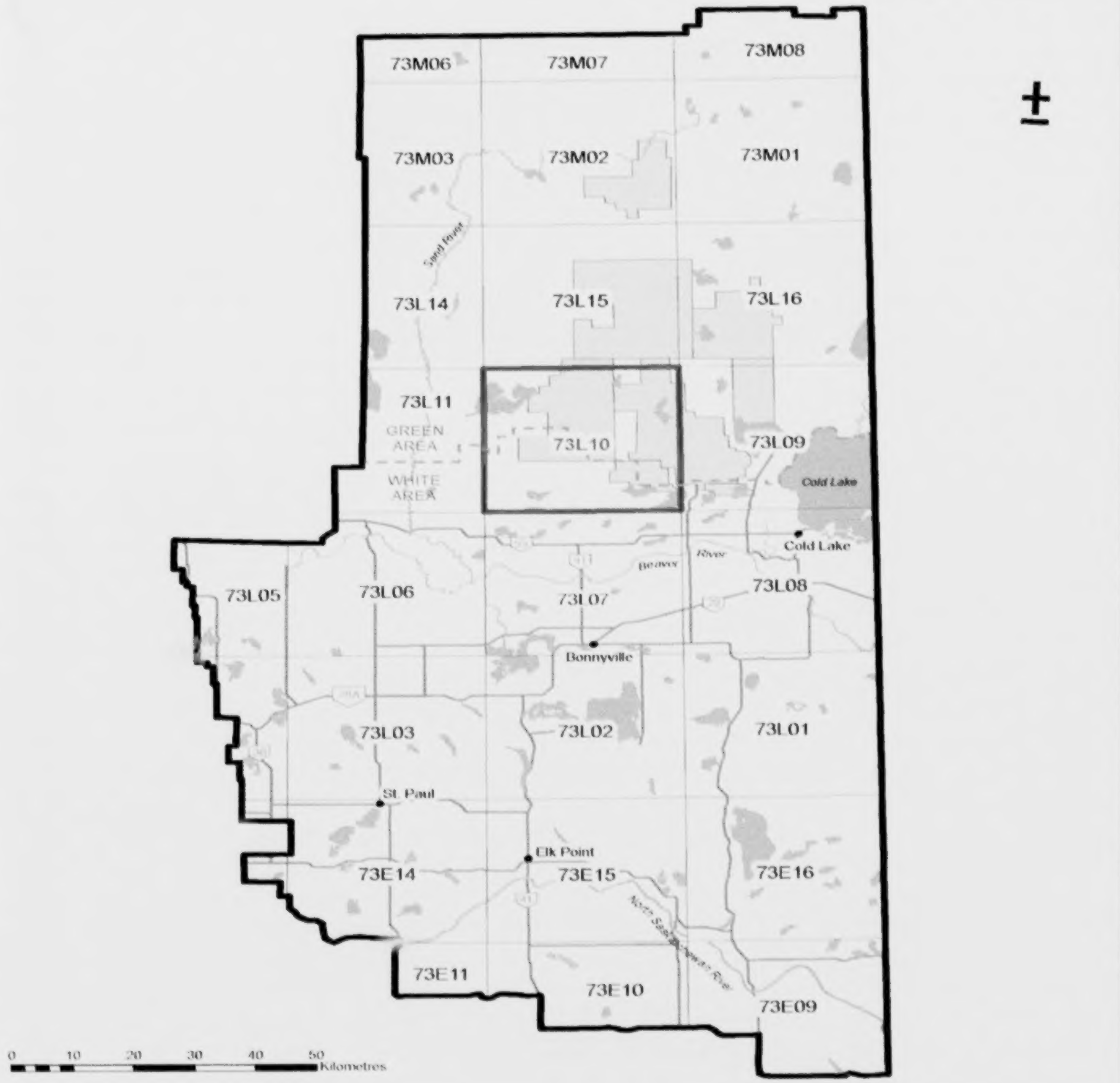
1.2.1 Landscapes and Habitat

Concepts and terms developed for the fields of landscape ecology and conservation biology provide a foundation to evaluate changes in landscape features, land disturbances, and reclamation progress over time. The following landscape ecology discussion is taken from Salmo *et al.* (2003) and was originally adapted from Jalkotzy *et al.* (1997):

Land is a **mosaic**, or a pattern comprised of three basic units: patches, corridors, and the matrix. These three landscape elements may be natural or of human origin. The **matrix** is the dominant background ecosystem or land use type in the mosaic. Within this matrix, **patches** and **corridors** are reasonably uniform areas and linear features that differ from their surroundings. The matrix and the type and arrangement of patches and corridors in that matrix determine the suitability of the landscape mosaic for different species and human activities.

Scale is an important consideration for cumulative effect evaluations. A **landscape** represents an area of tens to hundreds of square kilometres that includes a particular mosaic. A **region** may contain many landscapes but may not necessarily have a repeating pattern of landscapes or landscape elements. At this broader scale, the type and availability of landscapes determines the region's suitability for different species and human activities.

There are two main landscape types in the LICA region. In the forest landscape (Figure 2), there are treed patches of variable size, age, structure, and species composition. Unforested natural openings associated with waterbodies, wetlands, and low-growing vegetative cover also are present. Within this matrix, there are human-disturbed patches such as well sites and cut blocks, as well as disturbance corridors like roads, trails, and power line and pipeline rights-of-way. The landscape outside forested areas (the agricultural landscape, Figure 3) is a human-dominated matrix with remnant areas of native trees, shrubs, and grasses in patches and along corridors (e.g., windrows or along road ditches).



Legend

▭ In Situ Footprint Monitoring Project Area

▨ In Situ Development Area (approximate boundaries)

▭ Lakeland Industrial and Community Association Region

┆ Green - White Area Boundary

Cold Lake Air Weapons Range

▭ 1:50 000 NTS Grid

― Primary or secondary highway

● City / town

▨ Hydrography

Figure 1

Lakeland Industrial and Community Association Region

Data Sources:

In Situ Development Area - digitized from Energy Resources Conservation Board In Situ Progress Report (CNRL 2006)

LICA boundary - digitized from a map supplied by the Lakeland Industry and Community Association (2007)

Green White Area Boundary - 1:20 000 (2005) acquired in digital format from AltaLIS

Air weapons range - 1:20 000 Geoadministrative base features (2004) provided in digital format by ASRD

NTS grid (2007) - acquired in digital format from AltaLIS

Transportation features - 1:10 000 National Road Network (2007) acquired from GeoBase, Natural Resources Canada

Hydrography - 1:10 000 - 1:50 000 CanVec data (2007) acquired from GeoGratis, Natural Resources Canada

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

GIS and cartography on behalf of the ALCES Group by K. Manuel, Salmo Consulting Inc. and M. Sutherland, EcoBorealis Consulting Inc.

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13 June 2008

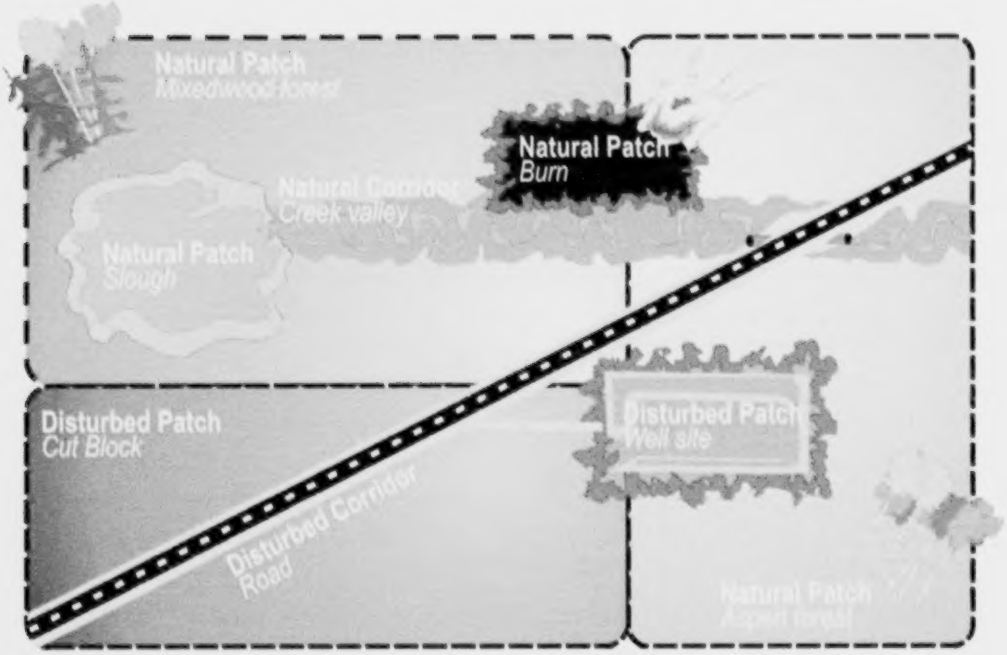

Figure 2. Elements of a forest landscape.

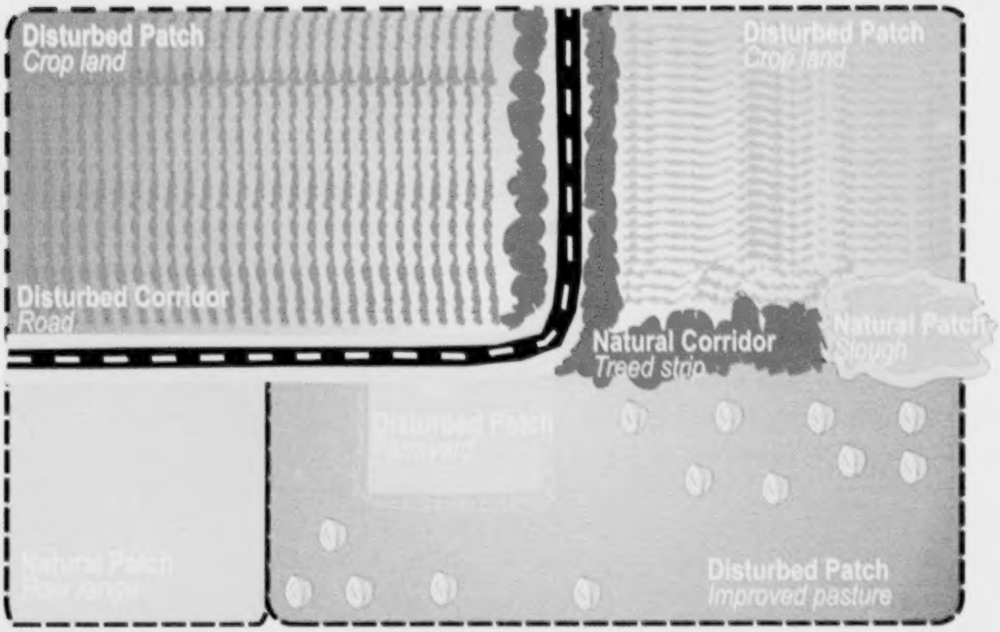

Figure 3. Elements of an agricultural landscape.

Terrestrial **habitat loss** occurs when human activities disturb the soil or remove vegetation and regrowth of native vegetation does not occur (e.g., construction of a highway, secondary road, or industrial facility). This **direct footprint** reduces or alters available habitat for all wildlife species and land users as long as the feature persists. Aquatic habitat loss occurs when water is removed, chemistry is substantially altered, or bed and banks are substantially altered.

Habitat alteration occurs until natural conditions are restored to the direct footprint. Long-term or permanent terrestrial habitat alteration occurs when different vegetation grows on the disturbed area (e.g., converting mixedwood forest to domestic grasses for hay production or reseeding a pipeline right-of-way with non-native agronomic species that prevent native species propagation). Permanent aquatic habitat alteration occurs when substrate or channel conditions are modified, or where flow and sediment transport patterns are modified by riparian or upstream activities.

Permanent habitat alteration can also result from the introduction of non-native or exotic species (Douglas *et al.* 1990) and changes in grazing patterns and intensity (Platts 1991). The spread of non-native plants is affected by their dispersal capacity and the quality of immediately adjacent habitat. Cattle and linear disturbance corridors, such as roads and trails, can facilitate the spread of these species (Fleischner 1994; van Dorp *et al.* 1997; Hobbs 2001).

Habitat alteration may also occur indirectly through 'edge' effects at the boundaries where a new patch or corridor meets the matrix. These create an **indirect footprint** that is additive to the direct footprint for many species and some land uses. As expanses of continuous vegetation are fragmented, edges between the patches and surrounding habitat increase in length. Edges are particularly noticeable in forested landscapes, because of their dominant vertical structure.

Moisture, light, temperature, and wind regimes may change significantly at edges, and these physical effects may extend into natural patches for tens of metres. Edge orientation will affect the amount of environmental change; windward and/or south-facing edges will be warmer, drier and wider than leeward or north-facing edges. With the altered environmental conditions, the structure and composition of edge plant communities generally differ from those in interior habitat. Other observed 'edge' effects include increased predation, mortality, competition, and brood parasitism; changes in vegetation diversity and structure; changes in species composition and abundance; and reduced wildlife use (e.g., van der Zande *et al.* 1980; Wilcove *et al.* 1986; Laurance and Yensen 1991; Collinge 1996; Reed *et al.* 1996; Bayne and Hobson 1998; ESGBP 1998; Bayne *et al.* 2005a, b; Machtans 2006; Antoniuk *et al.* 2007). Relatively undisturbed, natural habitat is found in the **core area** beyond the zone-of-influence of edge effects.

Edge effects are more pronounced in small or thin patches, since the ratio of edge to interior increases geometrically with decreasing patch size (Temple and Cary 1988; Collinge 1996; Culling and Anderson 2001). In very fragmented forests, virtually all remaining habitat may be so close to an edge that no functional core habitat remains (Temple and Cary 1988). For instance, if edge effects are assumed to extend 50 m from a patch edge, then a 1-ha square patch will contain no core habitat whatsoever while a 100-ha square patch will contain 81% core habitat (Figure 4). In contrast, a narrow 100-ha rectangular patch will contain only 69% core (Figure 5). Roads and other linear corridors create substantially more edge than clearings of equivalent area, due to patch geometry (Figure 5).

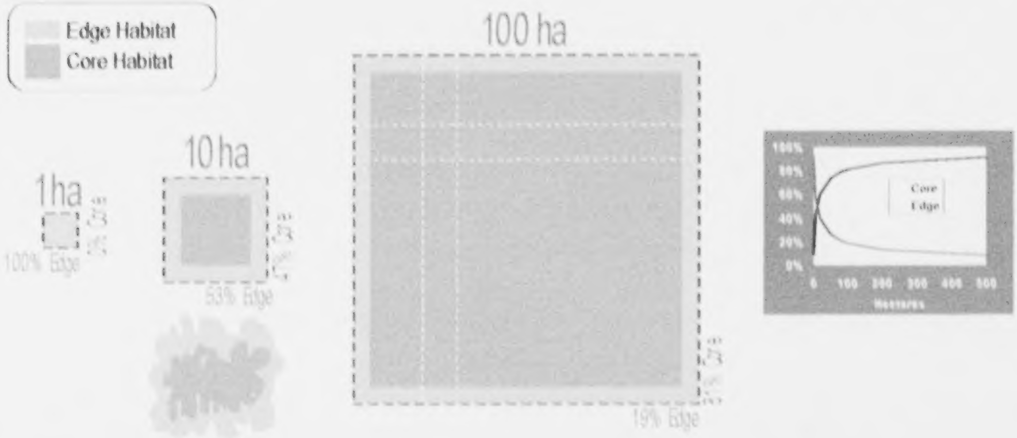

Figure 4. Relationship between patch size and edge area (the indirect footprint) assuming 50 m edge width (adapted from Collinge 1996).

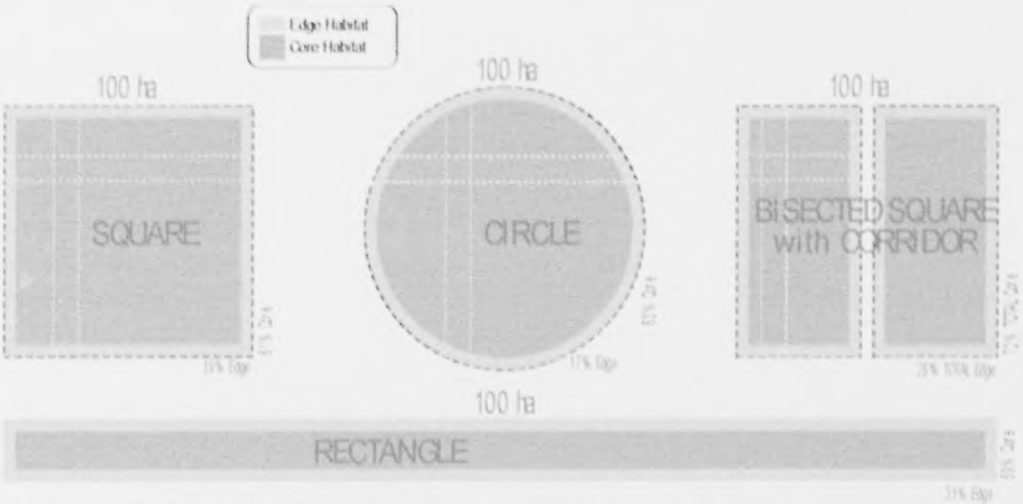

Figure 5. Relationship between patch geometry and edge area assuming 50 m edge width (adapted from Collinge 1996).

Habitat effectiveness ratings explicitly consider the influence of reduced habitat quality in both the direct and indirect footprints by deriving estimates of overall habitat quality that factor in habitat loss, habitat alteration, and edge effects. Overall, at any given scale, the combined direct and indirect footprint is more likely to affect habitat specialists and sensitive species such as woodland caribou and lynx than habitat generalists such as white-tailed deer and coyotes (Lord and Norton 1990; With and Crist 1995; Collinge 1996; Kolozsvary and Swihart 1999; Bayne *et al.* 2004).

In summary, to be most useful for integrated decision making and cumulative effects evaluation, monitoring indicators must allow changes in both direct and indirect footprints to be tracked or predicted over time. Also, ideally they should consider the influence of patch geometry, plant community condition, and sensitive or unique features.

1.2.2 Selecting Indicators

Limited time and resources make it impractical for resource managers, regulators, in situ proponents, and other stakeholders to consider or monitor all land use, ecological, and social factors. **Indicators** are commonly used to help focus assessment and management activities on important ecological and social components (Beanlands and Duinker 1983; Kelly and Harwell 1990; Noss 1990; Cairns *et al.* 1993; ELI 2003).

An indicator is defined here as:

> "a characteristic of the biophysical, ecological, or social setting that is used to describe, measure, manage, and report on resources of interest"

Indicators help land users and managers speak a 'common language' when they assess and manage cumulative impacts. Indicators are commonly used in 'State of the Environment' reporting for the same reasons. Indicators can be selected for either the resources themselves (e.g., wildlife population or plant community) or for the activities that create a stress on the resources (e.g., physical disturbance).

There has been considerable technical debate around the comparative merits of different indicators and monitoring approaches. A suite of complementary indicators generally is believed to be more appropriate for both resource management and decision making purposes because a single indicator is not capable of tracking all pertinent factors (Beanlands and Duinker 1983; Kelly and Harwell 1990; Noss 1990; Cocklin *et al.* 1992a, b; Cairns *et al.* 1993; FEARO 1994; Shoemaker 1994; Smit and Spaling 1995; Griffith 1998; Hegmann *et al.* 1999; Carignan and Villard 2002; GRI 2002; Macleod 2002; Schiller *et al.* 2003; Salmo *et al.* 2003; Dillon and Salmo 2006). However, no standard, widely-accepted suite of cumulative effect indicators currently exists.

Cumulative effect indicators generally take one of four forms:

- **Physical and chemical indicators:** air and water quality; animal body burden based on direct measurements or modelled conditions;
- **Ecological indicators:** habitat quality; species presence or relative abundance; biodiversity present in a defined area;
- **Social indicators:** economic performance, population dynamics, infrastructure and service availability, resource use, or individual or community well being.
- **Land and resource use indicators:** human activity intensity; direct and indirect footprint associated with linear corridors, clearings, industrial and commercial facilities, residential, and recreational sites.

Both issue-specific and generalized ecological and social indicators have been identified or proposed. Issue- or species-specific approaches use indicators of direct interest to resource managers (e.g., moose habitat effectiveness, area of old forest, soil nutrients). These indicators require information on plant composition and seral stage or soil properties that is often not readily available.

Generalized indicators are most commonly used to track regional trends of ecological conditions (e.g., habitat alteration and loss). These indicators are more practical for long-term monitoring because they provide information on cumulative impact risk and can be easily estimated from readily available information; however, they may not adequately document rare or sensitive site-specific features (ELI 2003).

Reviews of advantages and disadvantages of generalized and issue-specific ecological indicators provided in Salmo *et al.* (2003, 2004) and Dillon and Salmo (2006) provide more detailed information for interested readers.

Ecological indicators used in relevant provincial monitoring initiatives are summarized below as background to the discussion of recommended in situ indicators provided in Section 2.

1.2.3 Alberta Monitoring Initiatives

The mandate for land management in Alberta resides in multiple ministries including Sustainable Resource Development (SRD); Municipal Affairs; Agriculture, Food and Rural Development; Community Development; Energy, and AENV. Two recent monitoring program reviews commissioned by the Government of Alberta were considered for this project to ensure that in situ footprint monitoring will be consistent with existing and proposed programs. Summaries of relevant information from the AENV Land Monitoring Review project and Land Use Framework Monitoring and Evaluation Working Group project are provided below. This summary is followed by overviews of other provincial monitoring initiatives: State of the Environment reporting, biodiversity monitoring, and the Cumulative Effects Management Association (CEMA) program.

Land Monitoring Review

AENV established a Land Monitoring Review project in 2005 to provide an inventory of current AENV programs and a needs analysis for future land monitoring programs. The report commissioned for this project (Matrix 2006) identified the lack of sustainable development indicators as a critical gap and also defined three desired land monitoring outcomes:

1. assure that AENV is able to measure performance in achieving defined outcomes for environmental management;
2. assure that AENV's regulatory responsibilities for remediation, reclamation, and State of the Environment reporting are met; and
3. provide timely and accurate information to support Sustainable Resource and Environmental Management (SREM); integrated decision-making is guided by quality land monitoring information.

In situ oil sands operations currently are required to assess and permit their projects and reclamation programs for specific lease areas through regulatory processes such as the *Environmental Protection and Enhancement Act* and *Public Lands Act* approvals. Status of disturbances and reclamation progress is reported through annual Conservation and Reclamation reports. Unfortunately, existing permitting and reporting processes deliver limited and inconsistent regional information that is not sufficient for long-term monitoring of combined footprints and associated cumulative effects risk. Cumulative effects evaluations conducted for Environmental Impact Assessments are not incorporated into footprint mapping or cumulative effects mapping at the regional scale. In addition, permitting and reporting data are not currently presented in electronic form, and this discourages integration and evaluation of success (Matrix 2006).

The Land Monitoring Review concluded that indicators should be linked to desired land outcomes that have not yet been clearly defined at a regional or landscape scale. Land monitoring program components (and specific indicators) identified by this review included:

- riparian zone;
- watershed;
- reclamation success (vegetative quality is equivalent on and off reclaimed lands);
- landscape fragmentation (fragmentation percentage over time; land cover type by ecoregion);
- multiple land use and footprint (footprint over time; linear disturbance per hectare; percentage of land base in protective status, open status, urban, and industrial status);
- urban fringe; and
- landscape indicators in biodiversity monitoring.

Land Use Framework Monitoring and Evaluation

The Land Use Framework (LUF) Monitoring and Evaluation Working Group is one of four groups helping to articulate a vision that will guide the process of making land use decisions across the province and specifying the outcomes that this process should achieve. The Monitoring and Evaluation Group was asked to address three overarching questions to help achieve desired provincial outcomes:

1. What should we measure?
2. How should we measure it? and,
3. How should the measured results be used in a continuous improvement process?

The Monitoring and Evaluation Working Group report (in prep.) includes a summary of all provincial monitoring initiatives that may be relevant to land use decisions. The working group is proposing to use the Outcome Oriented Indicator Framework (Olsson *et al.* 2006) to structure a monitoring framework. This framework structures monitoring, evaluation, and reporting around the **outcomes** that one is trying to achieve, the **attributes** that define each outcome, the **condition indicators** that capture the state of the underlying systems and define each attribute, and the **influencer indicators** that affect or bring about changes in the state of the condition indicators. Suggestions of possible indicators are included in the report, with the expectation that a comprehensive list will be developed once the framework is approved and implemented.

State of the Environment Reporting

State of the Environment (SOE) reporting is required by the *Environmental Protection and Enhancement Act* and is part of AENV's mandate. As such, SOE reporting should be a natural extension of monitoring to document the condition of the land (Matrix 2006).

The first SOE report (AEP 1994) and subsequent terrestrial (AENV 1997) and wildlife (AENV 1999) reports did not specifically identify land indicators to be monitored, but reported on several indicators including:

- area of productive forest, wetland, agricultural land, and protected areas;
- forest loss from fire, insect pests and diseases;
- oil and gas infrastructure disposition numbers or combined footprint (where available);
- area of land disturbed, reclaimed and certified for oil sands mining, oil sands in situ, coal mining, and well sites; road length by class; and
- number of species of concern.

The SOE Comprehensive report (AEP 1994) notes that "further work is needed on indicators that measure the loss of natural habitat and impacts such losses have on biota".

Alberta's ongoing SOE reporting tracks five land indicators: Petroleum Storage Tank Site Cleanup; Area of Land in Parks and Protected Areas; Oil and Gas Well Reclamation; Coal Mining Development and Reclamation; Timber Harvest: Actual vs. Allowed; and Oil Sands Mining Development and Reclamation (online reporting available at: http://www3.gov.ab.ca/env/soe/index.html). The oil sands mining indicator specifically excludes in situ activities, and other indicators provide no information that enables the status of landscape features, land disturbances, and overall reclamation progress to be tracked over time in the LICA region.

Biodiversity Initiatives

The Sustaining Alberta's Biodiversity report (AEP 1998) identifies seven provincial biodiversity performance measures: Air Quality Index; Surface Water Quality Index; Reduction of Municipal Solid Waste to Landfills; Timber Sustainability; Species at Risk; Areas of Parks and Natural Reserves in Alberta; and Pulp Production versus Amount of Substance Discharged. Only the Species at Risk measure is directly relevant to monitoring the in situ land use footprint monitoring.

The Alberta Biodiversity Monitoring Institute (ABMI) has established a systematic province-wide monitoring program. Although human development is not considered a part of biodiversity, information on human development is often measured as part of a biodiversity monitoring program so that inferences can be made about why biodiversity has changed. The ABMI collects data on human activities using remote sensing. Information collected includes: area of human footprint by major category (i.e. ploughed land, logged stands, well sites and pipelines, and urban development), density of roads and other linear features, and human population (i.e., human residences). Most in situ footprints would be classified as 'commercial and industrial sites' or 'undifferentiated urban and industrial features' according to the Alberta Ground Cover Classification used by the ABMI (Sanchez-Azofeifa *et al.* 2004). Reported land indicators include: Total Amount of Habitat; Diversity of Habitat Types; Patch Size Distribution; and Density of Linear Features.

Cumulative Effects Management Association

The Cumulative Environmental Management Association (CEMA) has identified specific fish and wildlife indicators for the mineable oil sands area north of the LICA region. Several footprint and habitat variables (direct footprint, edge length, core area, old forest) are being tracked in the ALCES® computer model to develop projections of possible future fish and wildlife indicator conditions for different land management scenarios.

2. IN SITU FOOTPRINT MONITORING INDICATORS

2.1 SELECTION CRITERIA

Established land monitoring and reporting initiatives described above in Section 1.2.3 generally focus on individual land uses or stressors, and with the exception of the ABMI program, they do not support an integrated assessment of combined regional impacts attributable to multiple proponents and land uses.

The key criterion adopted for the In situ project was that selected indicators must allow the residual effects of both in situ and combined footprints to be evaluated and differentiated. Additional criteria used to select cumulative effect indicators for the LICA region were adapted from Noss (1990); Macleod (2002); NRTEE (2003); and Schiller *et al.* (2003). These additional criteria are described below under three general headings: 1) support existing management and decision making structures; 2) be practical to implement; and 3) be scientifically defensible.

2.1.1 Support Existing Management and Decision-making

To facilitate implementation, selected indicators should support existing provincial management and decision-making initiatives. Indicators that require new structures, processes, or monitoring programs are less likely to be accepted by decision makers and land users. For this project, selected indicators were chosen to be:

- able to provide information about desired provincial outcomes (ecological or social conditions and values);
- consistent with and able to be integrated with other existing provincial and regulatory monitoring programs (e.g., ABMI and project-specific reclamation monitoring);
- applicable to small through large projects [e.g., small site-by-site proposals reviewed by the Alberta Energy and Utilities Board (EUB) through large in situ development proposals reviewed by AENV and others as part of the Environmental Assessment Process];
- able to fulfill AENV's regulatory, performance monitoring, and reporting responsibilities (e.g., reclamation success and SOE reporting);
- capable of providing a continuous assessment from low through intensive land use (i.e., change measurable in both pristine and modified landscapes); and,
- applicable to other areas of the province and other land uses so that in situ pilot findings are readily transferable (e.g., applicable to grassland as well as forested natural regions).

2.1.2 Practical to Apply

To build stakeholder support and reduce monitoring costs, indicators should be obvious, easily measured and updated, and applicable to a wide variety of activities. Complex, time-consuming indicators are less likely to be implemented or consistently monitored. This ultimately represents a trade-off between a time-consuming and expensive process to develop the most accurate current footprint estimate and a less onerous process that generates less accurate results. Because the primary objective of long-term monitoring programs is to understand trends, results from individual points in time are deemed less important.

For similar reasons, indicators of ecological quality (e.g., wildlife habitat quality) were not selected because they require information on vegetation composition and seral stage, as well as land use. These specific relationships are important for management purposes and these analyses can still be undertaken if sufficient data exist.

To enhance practicality, indicators selected for in situ monitoring are intended to:

- be clear and understandable by communities, resource users, resource managers, and regulators (i.e., the reason for using each indicator is easily explained);
- use readily and publicly available, and reliable data where possible (i.e., minimize work required to obtain and verify monitoring data, recognizing that these data may be somewhat dated);
- be easy and cost-effective to measure or calculate (i.e., minimize analysis and reporting times);
- be reported and evaluated at multiple scales (e.g., local, sub-regional, watershed, regional, provincial);
- provide information for multiple key resources or support integrated evaluations for multiple key resources (e.g., species at risk), including predictive modeling; and,
- provide consistent, useful information over long time frames (e.g., generate long-term data from proponent and government monitoring programs that provides information useful for multiple resources).

2.1.3 Scientifically Defensible

Monitoring indicators must provide information that can be related to scientifically defensible relationships between land use and desired ecological or social outcomes. Indicators that provide information that is ambiguous or associated with poorly understood responses are less useful. As an example, direct and indirect footprint indicators provide more robust predictions of likely wildlife response than do habitat quality indicators.

To provide a scientific foundation for in situ monitoring, selected indicators are:

- based on reasonable understanding of relationship between indicator condition and potential cumulative effects (e.g., monitoring in north central Alberta demonstrates strong relationships between combined footprint and bird and mammal community composition);
- able to provide information on both project-induced and natural changes (e.g., existing boreal caribou statistical model includes coefficients for both natural burns and human-caused indirect footprint);
- taken as a suite, indicative of overall ecological and social conditions (e.g., footprint can be related to both wildlife community and individual species response, while habitat quality is generally associated with individual species only); and
- able to provide information on key cumulative effect pathways (e.g., direct and indirect effects that overlap in time and space).

Based on these criteria, a suite of generalized land use indicators is considered to be most appropriate for in situ oil sands footprint monitoring.

2.2 RECOMMENDED INDICATOR OVERVIEW

Eight generalized disturbance and reclamation indicators are recommended for the LICA area to fulfill AENV's mandate and to provide information for integrated decision making and management. These indicators are defined in Table 1, followed by a more detailed discussion of each in Sections 2.2.1 through 2.2.8 below.

This suite of disturbance indicators is designed to provide information about combined direct and indirect land use footprints that can be used to evaluate terrestrial and aquatic cumulative effects risks and associated risks to achieving desired provincial, regional, and sub-regional ecological and social outcomes. The suite of reclamation indicators defines how much footprint has been or is being reclaimed and its reclamation status relative to natural (pre-disturbance) landscape conditions. The net footprint indicator provides a simple measure of combined footprint less the area that has been restored to natural conditions.

Existing provincial disturbance and reclamation indicators are reported on a total area (i.e., hectare) rather than proportional basis. This makes it difficult for stakeholders and resource managers to understand the magnitude and scope of existing footprints for their area of interest. To provide the necessary landscape context, all recommended in situ indicators are scalable and intended to be reported as proportion of the pre-defined study area (i.e., 'place-based' for identifiable areas such as township, watershed, natural sub-region, map sheet).

Table 1. Recommended in situ oil sands footprint monitoring indicators.

In situ Monitoring Indicator	Description
DISTURBANCE INDICATORS	
Land Use Footprint (cleared area)	Proportion of analysis area where native vegetation or natural ground cover has been cleared or disturbed and ecological function has been affected.
Corridor Density	Average density of all linear corridors within the analysis area (km corridors/km^2).
Riparian Footprint	Proportion of riparian/wetland area where native vegetation or natural ground cover has been cleared or disturbed and ecological function has been affected.
Core Area (outside indirect footprint)	Area further than specified distance (in this case 200 m) from a linear corridor or land use feature where negligible to no effect on ecological function is anticipated.
RECLAMATION INDICATORS	
Certified Footprint	Proportion of analysis area for which Reclamation Certificates have been issued, but ecological function has been affected (i.e., non-native or incompatible vegetation community established).
Inactive Footprint	Proportion of analysis area where native vegetation or natural ground cover has been cleared or disturbed and land use has been discontinued, Reclamation Certificate has not been issued, and ecological function has been affected.
Restored Footprint	Proportion of analysis area for which Reclamation Certificate has been issued (where required) and ecological function has been restored (e.g., free to grow status reached for forested areas)
COMBINED INDICATOR	
Net Footprint	Proportion of analysis area where native vegetation or natural ground cover has been cleared or disturbed, less Restored Footprint (i.e., ecological function has been affected).

2.2.1 Land Use Footprint (Cleared/Disturbed Area)

The Land Use Footprint (cleared or disturbed area) indicator quantifies the combined area where native vegetation or natural ground cover has been lost or altered by land use corridors and patches (i.e., associated with in situ development, agriculture, forestry, industrial, residential, recreational and infrastructure sectors). As described below, this direct footprint affects native ecosystem function at the local scale and contributes to cumulative impacts at the landscape scale.

The Land Use Footprint indicator provides an index of overall terrestrial habitat availability as well as the level of fragmentation of the land base and watersheds. It can be applied in all ecosystem types and natural regions and should be reported in both hectares (ha) and as a percentage of the analysis area to allow loss of native vegetation communities, such as productive forest land, to be readily identified.

Rationale

Studies in temperate and tropical areas have shown a positive relationship between the area of suitable habitat and both biodiversity and species presence (Forman and Godron 1986, Seagle 1986, Flather and Sauer 1996; Schmiegelow and Monkkonen 2002; Price *et al.* in prep). Fire, clearing, and other forms of natural and man-made disturbance introduce changes into landscape patterns that affect the availability of specific habitat types. Cleared or disturbed areas may also create barriers to wildlife movement (Wilcove *et al.* 1986), and affect stream flow and water quality (Troendle and King 1985, Nip 1991, Minshall *et al.* 1997). Direct terrestrial habitat loss has been correlated with declines in fish abundance or distribution (Moscrip and Montgomery 1997, Wang *et al.* 1997, Pess *et al.* 2002, Scrimgeour *et al.* 2003, McLeary 2004).

Variations of the Land Use Footprint indicator are currently used in Alberta's ABMI program, SOE reporting, and CEMA initiative (Section 1.2.3 above). Direct footprint indicators have also been adopted in the Alberta Northern East Slopes Strategy (Regional Steering Group 2003), North Yukon Regional Land Use Plan (NYPC 2008), Muskwa-Kechika Management Area (MSRM 2004), and cumulative impact management frameworks developed for northeast BC (Salmo *et al.* 2003) and two regions of the NWT (Salmo *et al.* 2004; Dillon and Salmo 2006). Available literature suggests that overall risk of negative ecosystem effects can be related to cleared or disturbed area. For example, BCF and BCE (1995) identified the following risk ratings:

Low Risk of Adverse Ecological Effects: <18% cleared
Medium Risk of Adverse Ecological Effects: 18-36% cleared
High Risk of Adverse Ecological Effects: >36% cleared

2.2.2 Corridor Density

The Corridor Density indicator quantifies the total length of linear corridors (i.e., highways, roads, railways, pipelines, power lines, seismic lines, cutlines, and trails) per unit area (i.e., square kilometre). As described below, this indirect indicator is related to combined direct and indirect footprint, erosion risk, and mortality risk for terrestrial and aquatic ecosystems. It also provides an indicator of resource access for traditional, recreational, and industrial land use.

Rationale

Roads and other linear corridors are widespread features of most landscapes and are associated with negative effects on both terrestrial and aquatic ecosystem function (Trombulak and Frissell 2000). Access corridor density is considered to be the most useful landscape indicator because it integrates so many ecological impacts of roads, human use, and vehicles (Forman and Hersperger 1996, Trombulak and Frissell 2000, Forman *et al.* 2003). Road or access density is commonly used in SOE reporting (e.g., MLAP 2002).

Relationships between Corridor Density and species occurrence, habitat effectiveness, or population persistence have been developed for grizzly bear, birds, and boreal mammals (Thomas *et al.* 1979 and 1988, Lyon 1983 and 1984, McLellan and Shackleton 1988, Mace and Manley 1993, Reijnen and Foppen 1994, Jalkotzy *et al.* 1997, Anderson *et al.* 2002, Bayne *et al.* 2005a, b; Nielsen et al. 2007). In addition, increased road density also causes increased water yield and sediment transport to streams, increased number of movement barriers, and has also been correlated with declines in salmonid species, including bull trout (Jones and Grant 1996, USDA Forest Service 1996, Warren and Pardew 1998, Trombulak and Frissell 2000).

Road density is a biological diversity indicator that is: tracked in the ABMI program (see Section 1.2.3 above); adopted for the North Yukon Regional Land Use Plan (NYPC 2008); recommended for the Alberta NES Strategy cumulative effects management system (Regional Steering Group 2003); and included in cumulative impact management frameworks developed for northeast BC (Salmo *et al.* 2003) and two regions of the NWT (Salmo et al. 2004; Dillon and Salmo 2006). Available literature suggests that overall risk of negative ecosystem effects can be related to corridor density. For example, BCF and BCE (1995) identified the following risk ratings:

Low Risk of Adverse Ecological Effects: 0.0 to 0.9 km/km^2
Medium Risk of Adverse Ecological Effects: >0.9 km/km^2 to 1.8 km/km^2
High Risk of Adverse Ecological Effects: >1.8 km/km^2

2.2.3 Riparian Footprint (Riparian Disturbance)

The Riparian Footprint indicator quantifies the direct footprint within the riparian zone. The **riparian zone** includes wetland complexes and the land adjacent to a waterbody where the seasonal water table influences soil and vegetation (Figure 6). This zone is critical to both aquatic and terrestrial ecosystems. It provides habitat used at least seasonally by 80% of Alberta's wildlife (Cows and Fish n.d.), landscape movement corridors (Machtans *et al.* 1996; Lambert and Hannon 2000), nutrients and shade for stream channels (BCF 1999, BCF and BCE 1995; BCF and MELP 1999), and maintains water quality by capturing sediment and retaining surface and subsurface flow (Line and White 2007). Riparian disturbance has been shown to be inversely related to aquatic ecosystem function as explained in more detail below.

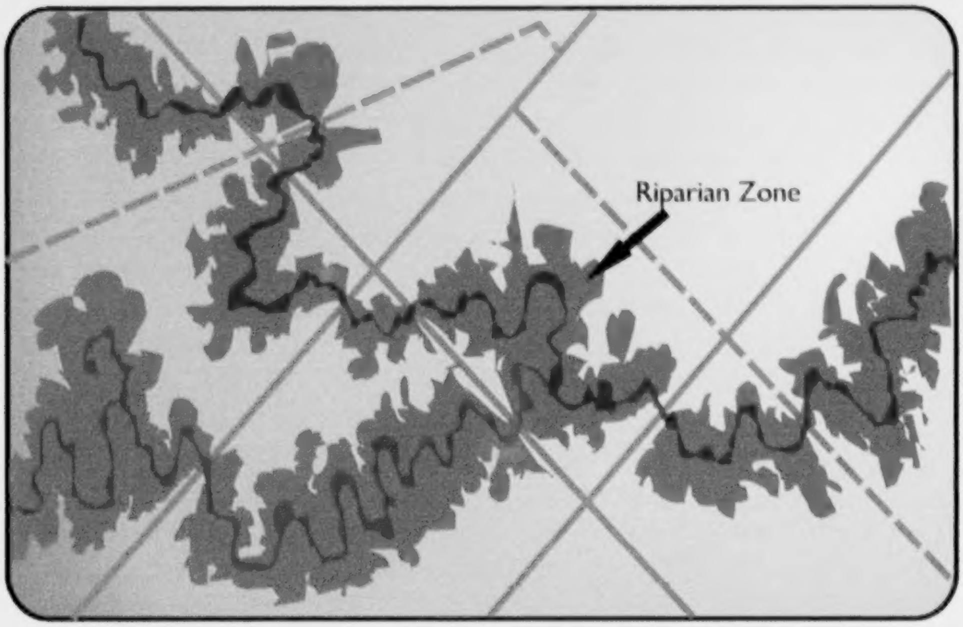

Figure 6. The riparian zone adjacent to waterbodies.

Rationale

Aquatic ecosystem integrity is lower in coldwater streams with reduced riparian vegetation (Hughes *et al.* 2004). A negative relationship between watershed disturbance and sensitive native species has been observed elsewhere (Eaglin and Hubert 1993, Frissell and Bayles 1996, Wang *et al.* 1997 and 2003). Several watershed and riparian metrics were included in the BC Interior Watershed Assessment Procedure (BCF and BCE 1995). A riparian disturbance indicator was the best predictor of waterbody condition in central Alberta's Battle River watershed (M. Sullivan, pers. comm.). Stream crossing density is a riparian disturbance indicator recommended within the Alberta Northern East Slopes Strategy (Regional Steering Group 2003).

The riparian disturbance indicator provides an erosion, habitat loss, and mortality risk index for aquatic ecosystem function. Available literature suggests that overall risk of negative ecosystem effects can be related to riparian footprint. For example, BCF and BCE (1995) identified the following risk ratings:

> Low Risk of Adverse Ecological Effects: 0-9% of riparian area disturbed
> Medium Risk of Adverse Ecological Effects: 9-18% of riparian area disturbed
> High Risk of Adverse Ecological Effects: >18% of riparian area disturbed

2.2.4 Core Area

Remaining Core Area was selected as a complementary ecological integrity indicator that quantifies areas relatively unaffected by disturbance. As described earlier in Section 2.1, relatively undisturbed core areas are found beyond a zone-of-influence or 'indirect footprint" immediately adjacent to man-made features. These indirect footprints become cumulative when the zones-of-influence from multiple land use features overlap in time and space (Figure 7). Increases in the direct and indirect footprint can lead to reduced productivity, biodiversity, and species abundance, particularly for sensitive or interior species such as woodland caribou, lynx, some songbirds, and grizzly bear.

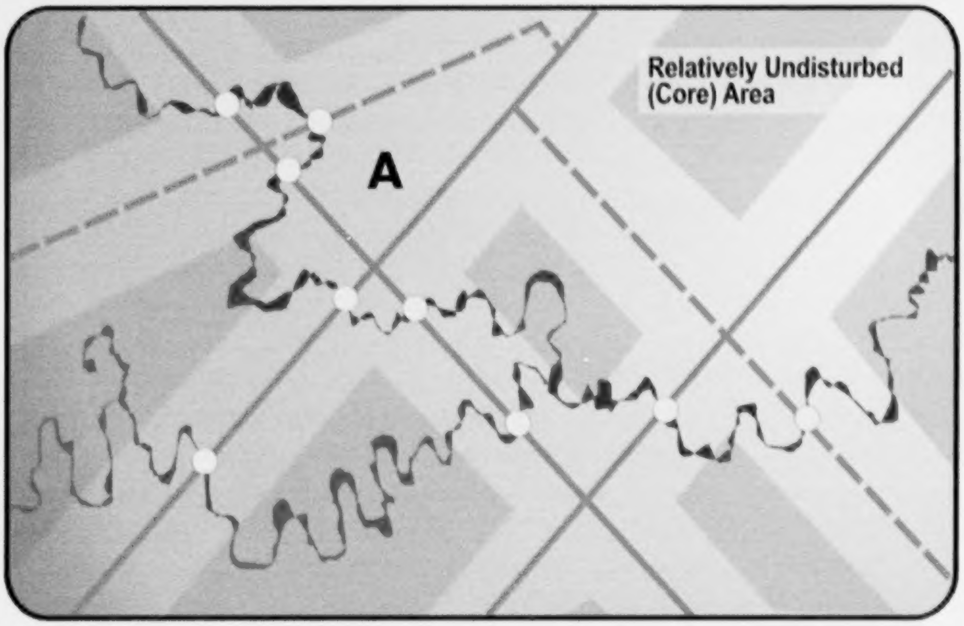

Figure 7. Core area remaining beyond direct and indirect footprint; area A represents patch with no remaining core habitat (Temple 1984).

Rationale

The Core Area indicator incorporates patch geometry by excluding patches that because of their shape have little or no interior area (Figure 7). Core (security) area analysis is an accepted assessment technique for grizzly bear (Cardinal River Coals Ltd. 1996, Gibeau *et al.* 1996, Noss *et al.* 1996) and has also been adopted for other physical and ecological evaluations (Laurence and Yensen 1991, Reed *et al.* 1996) and land management (Deh Cho Land Use Planning Committee 2006).

Core Area provides an indicator of relatively undisturbed or unaffected areas at the sub-regional and regional scales. The zone-of-influence around industrial, recreational, and community sites and activities depends on, among other factors, the resource being considered, the nature of the disturbance, and the season. In forested landscapes of Canada, core security habitat for bears is normally assumed to be 500 m from roads or other high use features and mortality risk is also increased in this area (*e.g.*, Gibeau *et al.* 1996, ESGBP 1998, Kansas 2002, Nielsen *et al.* 2004). This larger zone-of-influence is also the zone in which reduced use occurs seasonally for other sensitive species such as trumpeter swan (Henson and Grant 1991), and woodland caribou (Antoniuk *et al.* 2007). Total area within 250 m of a land use feature is one of the best predictors of woodland caribou mortality risk in Alberta and British Columbia (BCC 2003, Antoniuk *et al.* 2007). A 250 m zone-of-influence is considered to be too large for forest bird communities because, while narrow corridors may act as barriers or filters to boreal forest birds, they do not appear to create large zones-of-influence with reduced bird use (Bayne *et al.* 2005b).

A 200 m zone-of-influence was adopted for the In situ project to be consistent with that used in the CEMA oil sands initiative immediately north of the LICA region. This zone-of-influence was selected as a reasonable average based on a literature review of behavioural response by ungulates, carnivores, and furbearers (B. Stelfox pers. comm.). Different zones-of-influence can be easily applied if appropriate for future projects or different natural regions.

Available literature suggests that overall risk of negative ecosystem effects can be related to core area. For example, Dillon and Salmo (2006) identified the following risk ratings:

Low Risk of Adverse Ecological Effects: >90% core
Medium Risk of Adverse Ecological Effects:40-90% core
High Risk of Adverse Ecological Effects: <40% core

2.2.5 Certified Footprint

The Certified Footprint indicator quantifies areas where active human land use has been discontinued and the decision of a land manager indicates that equivalent land capability has been returned (i.e., a Reclamation Certificate has been issued). This identifies the portion of the landscape where disturbance has been discontinued, but habitat may have been permanently altered. It also identifies areas that could be restored – where necessary – in the short- to medium term to reduce cumulative risk to native ecosystem function.

Rationale

According to AENV (1995), the current goal for reclamation in Alberta is to return disturbed land to a state of equivalent capability (i.e., potential uses of the land following reclamation are similar to, but may not necessarily be the same as, that which existed prior to the industrial activity taking place). This difference is important for understanding risks to achieving ecological and socio-economic outcomes because these 'reclaimed' areas may not support the full suite of pre-disturbance opportunities (e.g., sites returned to self-sustaining non-native grass cover will not return to natural forest vegetation for many years, if ever, thereby affecting quality for species and resource uses that depend on mature forest).

The reclamation criteria to be followed depends on the land use – cultivated, grassland, forested (white area), forested (green area) and peat areas. Requirements for each can include landscape, soil quantity, soil quality, soil profile, and vegetation parameters. Applications are submitted to AENV for private land and Alberta Sustainable Resource Development (ASRD) for public land. Once a Reclamation Certificate is issued, there is no further assessment requirement though surface liability remains with the licensee for 25 years, at which time it reverts to the government.

Vegetation measures specified by AENV (1995) reclamation criteria include:

- **Species Composition** - revegetation species and species composition should be compatible with original or adjacent vegetation or meet reasonable land management objectives; and

- **Cover** - where there is no adjacent vegetation or the adjacent vegetation is different, ≥80% cover of plants, litter and woody debris.

The Certified Footprint indicator is designed to provide information on regional reclamation success and fulfill AENV's reporting mandate by explicitly monitoring the area where reclamation has (or has not) been achieved. This is necessary to allow combined net footprint within a region or study area to be monitored over time.

2.2.6 Inactive Footprint

The Inactive Footprint indicator quantifies areas where active human land use has been discontinued but the site has not yet been reclaimed or restored. This provides an indicator of the altered land base that could be restored in the medium term to reduce cumulative ecological risk. Tracking the Inactive Footprint indicator should help focus cooperative efforts to reduce the number and area of inactive sites and corridors, accelerate regional restoration, and minimize long term risks to native ecosystem function.

Rationale

This indicator is similar to an AENV performance measures used to evaluate Alberta's Upstream Oil and Gas Reclamation and Remediation Program: namely, the ratio of certified upstream oil and gas well and production sites to abandoned upstream oil and gas sites (AENV 2007a). This ratio is a comparison of the number of sites awaiting reclamation or submission of reclamation certificate applications to those certified on public/private land. The goal of this program and other past and ongoing EUB initiatives (EUB 1997; 2000) is to increase the number of abandoned sites that are reclaimed each year.

Disadvantages of the current AENV performance measure are that it tracks only the number of inactive well and production sites and does not consider the area of those sites, nor linear corridors such as seismic lines, power lines, and pipelines. This makes it difficult to relate reclamation status to landscape- or ecosystem scale function (Smyth and Dearden 1998).

The Inactive Footprint indicator is designed to address these disadvantages by explicitly tracking the area of all industrial, commercial, agricultural, residential, and transportation footprints in a consistent manner. This is necessary to allow combined footprint to be monitored over time.

2.2.7 Restored Footprint

The Restored Footprint indicator quantifies areas where self-sustaining native vegetation has been returned to disturbed sites and corridors **and** a Reclamation Certificate has been issued where required. In forestry terms, this is equivalent to 'Free to Grow' with compatible native vegetation/trees. This provides an indicator of the altered land base that is on a natural succession trajectory and where cumulative risk to natural ecosystem function is negligible.

Rationale

Vegetation recovery is a commonly used indicator of ecosystem function (Ruiz-Jaen and Aide 2005). The Restored Footprint indicator is designed to provide information on regional restoration success by explicitly monitoring the area where restoration has (or has not) been achieved. This is necessary to allow combined net footprint to be monitored over time.

Historical reclamation practices in the Green Area based on return of equivalent land capability have not been successful in re-establishing a forest ecosystem. Past reclamation focused on the development of rapid vegetation growth to meet the minimum 80% cover requirement, which generally resulted in establishing grass and forage cover, and inhibited tree and shrub regrowth (AENV 2007b). This means that many Certified Footprints would not be considered 'Restored' using the criteria provided in this protocol.

Recent AENV direction identifies natural forest ecosystems (i.e., natural ecological function) as the desired reclamation outcome for oil and gas sites in the Green Area (AENV 2007b). The update document provides clarification on the landscape, soil and vegetation criteria expectations for forested lands in the Green Area. Specifically the vegetation criterion is clarified to include herbaceous and woody vegetation cover that is compatible with adjacent forest. Sites constructed following the release of this document will have to comply with the update document. Sites abandoned/reclaimed following the release of this document will have to comply with most parts of the update.

In the White Area, separate reclamation criteria have been developed for cultivated lands, grasslands, and forested areas (AENV 1995). In most cases, restoration of cultivated lands will not occur. In addition, cultivated land reclamation criteria reflect surface soil quality and crop/forage growth and these detailed 'quality' data are not readily available at the landscape scale. For these reasons, cultivated land reclamation will be included only in unusual instances where they are restored to native vegetation communities.

Reclamation criteria for grasslands and forested lands in the White Area are also based on surface soil quality and vegetation growth. For long-term monitoring purposes native grassland and forest sites in the White and Green Areas should be considered Restored where self-sustaining native vegetation occurs and a Reclamation Certificate has been issued.

2.2.8 Net Footprint

The Net Footprint indicator quantifies the cumulative land footprint, excluding areas that have been returned to pre-disturbance successional trajectories. Quantification of other indicators described above is a prerequisite.

3. INDICATOR MONITORING PROTOCOL

This protocol describes the steps necessary to calculate the values of the recommended in situ monitoring indicators (Section 2) and to map the cumulative net footprint.Generic instructions are provided along with details specific to applying the protocol for the selected In situ project study area.

3.1 PROJECT AND STUDY AREA SELECTION

For the In situ project, the area of interest was based on stakeholder interests around in situ oil sands development and was defined as the LICA region. The critical first step in regional or landscape monitoring is to define the project area and specific study area(s) within this area of interest. Project and study area boundaries may be defined by administrative units (e.g., township or municipal district); consistent ecological units (e.g., natural subregions or ecoregions); physical features (e.g., watersheds); or data availability.

The following rationale for selecting the In situ project area can also be applied to other monitoring initiatives.

> **Setting**: Existing and proposed in situ oil sands developments in the LICA region are located within Townships 62 through 71, Ranges 2 through 8, W4M within the predominantly forested Green Area (Figure 1). Land use in the White Area to the south is a mosaic of mixedwood boreal forest, lakes, agricultural clearings, the Cold Lake military base, rural residences, conventional hydrocarbon and transportation infrastructure, and communities.
>
> **Data Availability**: The project team reviewed the availability of satellite and aerial imagery for the LICA region and found that 1981 aerial photography at a scale of 1:30,000 was available for most of the 70 township in situ development area. The resolution of historical satellite imagery was concluded to be inadequate to delineate small, but regionally important features such as seismic lines and trails. Current high resolution (<2m) satellite imagery could be used for future monitoring.
>
> **Project Objectives**: The 73L10 National Topographic System (NTS) 1:50,000 map sheet (Figure 8) was selected as the overall study area to demonstrate the monitoring protocol. This 898 km^2 area (hereafter referred to as the **project area)** includes 4 complete townships and portions of 8 additional townships. This scale is both ecological relevant and appropriate for demonstrating footprint monitoring constraints and issues. In addition, working on a map sheet or township basis allows future regional or provincial monitoring costs to be easily extrapolated from this pilot project.

More specifically, the 73L.10 map sheet area was selected because it:

- includes several existing in situ developments as well as agricultural and residential land uses;
- has suitable historical imagery from 1981;
- overlaps the Green Area/White Area administrative boundary;
- includes ecological and administrative boundaries to demonstrate how footprint monitoring can simultaneously be related to terrestrial ecological boundaries (Dry Mixedwood and Central Mixedwood Boreal Forest Natural Subregions), aquatic ecological boundaries (Jackfish and Sand drainages), administrative boundaries (townships), and mapping boundaries (complete topographic map sheet); and
- has Environmental Impact Assessments that describe existing and likely future conditions in this area that may be useful for comparative purposes.

Multiple **study areas** were selected for analysis within the project area were adopted for the In situ project to demonstrate how indicator analyses can be completed and reported for the overall project area as well as designated subunits. Study areas used for the In situ project were:

Natural Subregion:	Central Mixedwood and Dry Mixedwood
Township:	Twps. 64-66, Rges. 4-7, W4M (note: a very narrow portion of Township 63, Ranges 4 to 7 (~50 m band along the north edge of the township) is present along the southern boundary of mapsheet 73L.10, because of the small area involved indicators are not reported for these townships).
Watershed:	Manotokan-Jackfish (Jackfish) and Wolf-Sand (Sand)

For the In situ project large waterbodies were defined as lakes greater than 100 ha, and they comprised almost 9% of the project area. Indicator reporting for the study area (i.e., map sheet), natural subregions, and townships excluded large lakes (terrestrial analysis area), while indicator reporting by watershed included large lakes (aquatic analysis area).

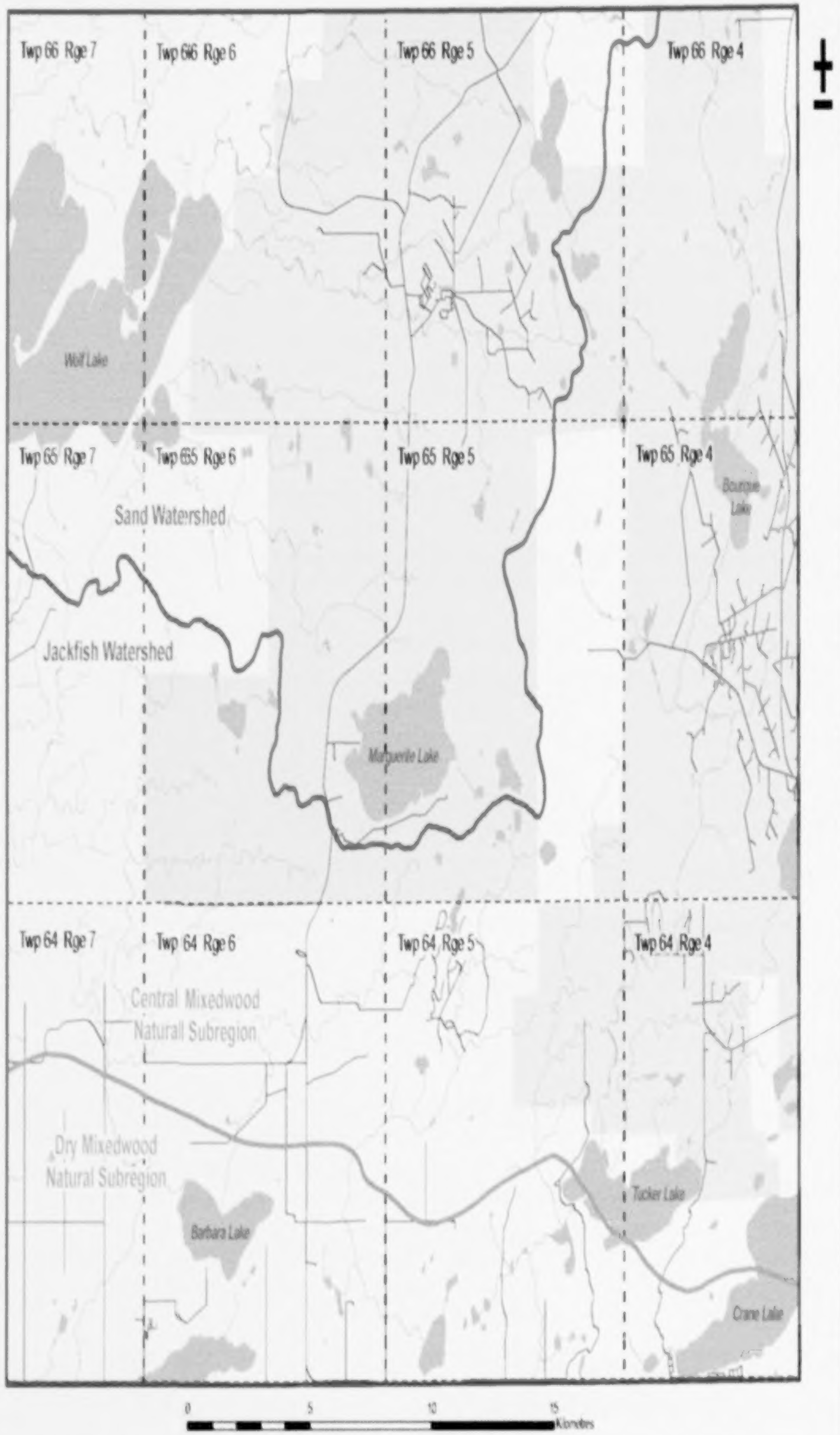

Figure 8

Study Area Boundaries for the In Situ Project Area (73L10)

Legend

☐ In Situ Footprint Monitoring Pilot Project Area

- - - - Alberta Township System (ATS) grid (W4M)

—— Natural Subregion boundary

—— Watershed boundary

▨ In Situ Development Area (approximate boundary)

—— Paved road

—— Unpaved road

▨ Water body

—— River

Data Sources:

ATS grid 1:20 000 (2005) and Natural Subregion boundary 1:250 000 (2005) provided in digital format by Alberta Sustainable Resource Development (ASRD)

Watershed boundaries 1:50 000 (2008) acquired in digital format from Prairie Farm Rehabilitation Administration (Agriculture and Agri-food Canada)

In Situ Development Area digitized from Energy Resources Conservation Board In Situ Progress Report (CNRL 2008)

Transportation features 1:20 000 (2001) and hydrography 1:20 000 (2000) provided in digital format by ASRD

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

GIS and cartography on behalf of the ALCES Group by K. Manuel, Salmo Consulting Inc. and M. Sutherland, EcoBorealis Consulting Inc.

Although there is no reason to believe there are any errors associated with the data used to generate this product or in the product itself, liability of Salmo Consulting Inc. and EcoBorealis Consulting Inc. is limited to the purchase price of the service provided.

Map not suitable for navigation.

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3.2 DATA ACQUISITION AND ANALYSIS

3.2.1 Data Acquisition - Current Time Period

For the In situ project, readily available data, and specifically ASRD digital 1:20,000 base feature maps, were considered to be the most cost-effective method to document the current land use footprint. While these data may not be as accurate as recent imagery, base feature data are updated on an ongoing basis using satellite and aerial imagery (AltaLIS 2008), and provide a cost-effective platform for regional-scale monitoring initiatives.

Base feature data for the project area were updated between 2001 to 2007 depending on the base feature theme. The access theme, which contains most of the data relevant to this project, was updated in 2001. Other data sources were used where gaps in the base feature data were noted. For example, Energy Resources Conservation Board (ERCB) well and facility data were obtained from a third party distributor, and Alberta Vegetation Inventory (AVI) data from ASRD included borrow pit, cutblock and agricultural land use footprints. It should be noted that ASRD had also purchased the ERCB well and facility data purchased from a third party, but these data were not available for the In situ project due to data sharing agreement restrictions (H. Evans pers. comm.).

Data sources and land use footprint classes used for the In situ project are summarized in Table 2. For this project, data were acquired for the 73L10 map sheet as well as an approximate 1.5 km buffer around the map sheet. These additional data were required to address boundary issues associated with the Corridor Density analyses (Section 3.3.2).

Some issues to consider once data are received include the following:

- that data are provided for the requested area and the requested features (e.g., for the In situ project, ERCB well data was initially provided with only downhole locations whereas for surface disturbance, surface hole locations are required);
- that data are provided in the correct projection (e.g., data was provided for the In situ project in UTM Zone 12 NAD 83 coordinate system); and
- if data are provided in a series of tiles, edge matching may be considered necessary. For the In situ project, data were provided in one complete tile, and given the coarse scale of the indicator analyses, edge matching would not be considered necessary.

Table 2. Land use footprints and data sources for the In situ footprint monitoring pilot project study area (current time period)

Land Use Footprint Type	**Data Currency**	**Data Source**
Airstrips (none identified)	2001	ASRD – access base feature theme
Borrow Pits	2005	ASRD – Alberta Vegetation Inventory (AVI) data
Communities 200	1, 2005	ASRD – geoadministrative areas base feature theme and AVI data
Crop/Pasture Land	2005	ASRD – AVI data
Cutblocks	2005	ASRD – AVI data
Cutlines, Snowmobile/ATV trails	2001	ASRD – access base feature theme
Industrial Facilities	2001, 2005, 2007, 2008	ASRD- access base feature theme, AVI and cadastral data; IHS Energy[1]
Mines and Quarries	2001	ASRD – access base feature theme
Other Clearings (none identified)	2001	ASRD – access base feature theme
Paved Roads and Highways	2001	ASRD – access base feature theme
Pipelines	2001	ASRD – access base feature theme
Power Lines	2001	ASRD – access base feature theme
Railways (none identified)	2001	ASRD – access base feature theme
Recreational Facilities	2001	ASRD – access base feature theme
Recreational Trails (hiking/skiing/biking)[2]	2001	ASRD – access base feature theme
Rural Residential/Cabins	2001, 2005; 1981	ASRD – access base feature theme and AVI data; 1981 Imagery
Secondary Roads	2001	ASRD – access base feature theme
Truck Trails and Rough Roads	2001	ASRD –access base feature theme
Wellsites 200	8	IHS Energy

[1] IHS Energy: third party distributor for ERCB well and facility data

[2] Recreational Trails: ASRD base feature data provided an area set aside for the Wolf Lake Forest Recreation Trail –a specific trail location was not provided. This was used in the Core Area analysis only.

3.2.2 Data Acquisition - Historical Time Period

Both historic satellite imagery and aerial photography can provide historical footprint data. As indicated in Section 3.1, the resolution of historical satellite imagery was concluded to be inadequate to delineate small, but regionally important features such as seismic lines and trails. A review of available aerial photography however, revealed 1981 aerial photography at a scale of 1:30,000 was available for the project area.

For the In situ project, Tarin Resource Services Ltd. conducted high resolution scanning of the 1981 photo diapositives provided by ASRD. The images were **orthorectified** and a mosaic was created for each of four quadrants (NE, NW, SE, SW) of the project area. Data were provided in UTM Zone 12 NAD 83 coordinate system.

The orthorectified imagery was used as a guide for developing the 1981 footprint. The current footprint was overlayed on the orthorectified 1981 imagery; land use footprints that did not exist in the 1981 imagery were removed from the current dataset resulting in a comparable dataset of land use footprints existing in 1981. Additional information on this process is provided in Section 3.3.1, Step 3.

3.2.3 Data Analysis

A Geographic Information System (GIS) (i.e., ArcGIS - a product of Environmental Systems Research Institute, Inc.) was used to map historical and current land use footprints and prepare data for analysis. Data in ArcGIS were saved as personal geodatabases, which are stored as Microsoft Access (MS Access) files. MS Access was used to complete the analyses of all indicators.

3.3 INDICATOR ANALYSIS

3.3.1 Land Use Footprint

Land use footprint, or cleared/disturbed area, calculations include all forms of surface disturbance that could affect plants, vegetation communities, wildlife habitat, aquatic ecosystems, visual values, or human use. For the In situ project, this direct footprint indicator was calculated for the project area and multiple study areas (i.e.,natural subregions, major drainages, and individual townships), for both the historical and current time periods.

The steps required to create a dataset for calculating the Land Use Footprint indicator are provided below in Table 3. Information relating to application of the each step to the In situ project is also provided.

Table 3 Land Use Footprint indicator analysis steps.

Step 1	Compile data for all existing Land Use Footprints, and create separate GIS layers for each footprint type (e.g., paved roads and highways).
Step 2	Determine the cleared area of each land use footprint type for the current time period, and create individual land use footprint layers.
Step 3	Develop individual land use footprint layers for the historical time period.
Step 4	Establish a hierarchy for overlapping footprints.
Step 5	Create a single footprint/cleared area layer by combining the individual footprint layers based on the hierarchy.
Step 6	Report hectares and percentage of each land use footprint present within the project area or study area(s).
Step 7	Visually present Land Use Footprint/cleared area results in maps specific to the project area or study area(s).

Step 1. Compile data for all existing land use footprints, and create separate GIS layers for each footprint type (e.g., paved roads and highways).

A separate **layer** was created in the GIS for each existing land use footprint type (Table 2 in Section 3.2.1). Some footprint types (e.g. airstrips and railways) were not present in the In situ project area. More detailed information or issues associated with this step include:

ASRD base feature data classification: Some grouping of features into the listed land use footprint types was required. This grouping process was based partially on the level of use expected for that footprint. For example, the ASRD base feature data identified areas occupied by fire lookouts and major mill sites. Based on estimated use, fire lookouts were grouped in the rural / residential cabin footprint type, and a mill site was considered an industrial footprint. Refer to Appendix A for information on base feature classification into land use footprint types.

ASRD AVI data classification: AVI data, which was used for identifying crop and pasture land, cutblocks, rural residences and borrow pits, was classified based on vegetation (ASRD 2005). Non-vegetated and grasslands such as rural residences and borrow pits were based solely on the AVI classification.

For cutblocks, some interpretation of the AVI data were required. Clearcut areas less than 20 years old where the extent of loss of crown closure was severe or entire (i.e., 76%-100% of the area was affected), were selected as representing the cutblock land use footprint type for the In situ project. The AVI data, however, did not always provide cutblock ages.

The 20 year date was applied for cutblocks as it was assumed that blocks greater than 20 years old have less impact on ecological or aesthetic values because they have obtained sufficient cover and height.

Refer to Appendix A for more information the classification schemes used to identify cutblocks in the AVI data.

Data availability and accuracy: As indicated, cutblock data were obtained from the AVI dataset for the In situ project area. There are three concerns with this data source.

Firstly, as indicated above, the AVI data provided by ASRD was not complete in some aspects (i.e., cutblock age was not always provided).

Secondly, the AVI data provided by ASRD are not updated on a regular basis. The data used for the In situ project were last updated in 2005, though for other crown lands in the province the data dates back to the early 1990s (H. Evans pers. comm.).

Thirdly, AVI data may not be available from ASRD if the project area is situated within a Forest Management Agreement (FMA) area. The FMA holder owns and maintains the AVI data and is responsible for sharing the data with ASRD; however it is unclear how comprehensive the data sharing process is.

Choosing data from different sources: Pipeline data were included in the ASRD Access base feature theme. These data are based on the interpretation of aerial photos or satellite imagery and thus reflect a footprint on the land. ASRD pipeline data were used for the In situ project in preference to ERCB pipeline data because ERCB information is based on applications rather than footprints, and are more likely to overestimate the number of pipeline rights-of-way.

Combining datasets: Most of the footprint data for the In situ project were obtained through ASRD and were last updated in 2001; however, well data, were obtained from IHS Energy based on ERCB records current to January 2008. To provide a comparable dataset of cleared area footprints, only data for wells initiated prior to 2002 were included from the ERCB data for the existing footprint.

Cadastral data: Cadastral data were available for parts of the In situ project area. Cadastral data are accurate as they depict legal property boundaries and ownership; however, this dataset is difficult to use because of the processing time for converting features represented by a series of lines to polygons, and the attribute data were not consistent.

Step 2. Determine the cleared area of each land use footprint type for the current time period, and create individual land use footprint layers.

Land use feature data were provided in three different formats: **point**, **line**, and **polygon** data. In order to measure cleared area, all footprints must be represented as polygons - point and line data do not have inherent areas. For the In situ project, linear features (i.e., roads, cutlines, power lines and pipelines) were provided in line format, and oil and gas wells and small facilities were represented as point locations. Each point feature type was assigned a standard area and each line feature type was assigned a standard width (Table 4), thus creating polygons that would represent the estimated surface disturbance. Standard area and width values were based on previous landscape analyses conducted by ALCES Group members. More detailed information and issues associated with this step include:

Polygon data: The AVI data and some ASRD land use features from the access base features theme were in polygon format. Base feature data and AVI are updated by ASRD using aerial photos and satellite imagery. For AVI data there may also be a field verification component.

Assumptions of footprint size: The assigned sizes and widths of land use features (Table 4) were based on reasonable assumptions, though ideally, actual footprint data should be used, if available.

> ERCB oil and gas facilities (point features) were assigned an area between 1 ha and 4 ha based on the type of facility (e.g., meter station, injection well). These sizes were derived from a review of cadastral data for the study area. The 1 to 4 ha polygons were created using a zero rotation angle which may not be a true representation of the footprint.
>
> Road widths were based on road dimensions standard to many parts of the province.

Creating polygons from line data: A common mistake when converting linear features to polygons is using the incorrect buffer size on either side of the line feature. For example a primary road is estimated to result in 50 m wide cleared right-of-way, so the line feature should be *buffered by 25 m on either side* to create the approximate footprint of a primary road.

ERCB well point data: The ERCB well data are intended to be a comprehensive list of wells drilled in the province and include information such as bottom hole location, drilling dates, operator / licensee, status and drill depth. The dataset can include multiple wells drilled within one wellbore, or in close proximity on another on the same well pad. The data do not intended to provide an indication of cleared area for either individual or multiple well leases.

Creating polygons from wellsite point data: Surface well point locations were converted to 110 by 110 m square polygons, or 1.2 ha assumed lease areas. This wellsite size is representative of conventional oil and gas leases. SAGD operations however, often result in multiple well pads where the lease size varies depending on the number of wells drilled from the one site.

> The issue of multiple wells drilled in one wellbore or multiple wells drilled in close proximity on one pad, results in a number of 1.2 ha polygons layered over each other. Overlapping wellsite polygons were combined to create one larger polygon to represent the cleared area for that series of wells. While this process likely does not accurately reflect the actual surface area disturbed, it is based on the only readily available well data.

Feature types tracked separately: **Fields** identifying the data source and feature type were added to the data at this stage in order to allow feature types to be tracked separately once the layers are combined. Field names must be identical in each of the individual cleared area layers.

Data consistency, accuracy and currency concerns: Readily available data for the current landscape ranged in date from 2001 (ASRD base features data) to 2008 (ERCB well data). In addition, some land use features in the current footprint were based on data that did not have associated surface footprint information (ERCB well and small facility data). And lastly, the accuracy or completeness of some of the data were questionable (e.g., AVI cutblock data).

Step 3. Develop individual land use footprint layers for the historical time period.

The individual footprint layers for the historical footprint were developed by overlaying the current footprint layers on the orthorectified 1981 imagery. Land use features that did not exist in the 1981 imagery were removed from the current dataset resulting in a comparable dataset of land use features existing in 1981.

Some land use features may have changed over time, for example, a cutline in 1981 may have become a secondary road in the current landscape. Land use feature types were updated as required to reflect these changes. Land use footprints were assumed not to have changed in size from 1981 to the current time period (e.g., no reduced seismic line width due to low impact seismic methods).

Table 4 Size and hierarchy of land use footprint types.

Land Use Footprint Type	**Hierarchy**	**Footprint** Average Area (ha) for polygon features or Width / Diameter (m) for linear features
Communities 1		Polygon size[1]
Paved Roads and Highways	2	50 m
Mines and Quarries	3	Polygon size
Industrial Facilities (e.g., meter stations to compressor sites)	4	Polygon size or 1 to 4 ha[2]
Secondary Roads	5	20 m
Railway 6		20 m
Airstrips 7		Polygon size
Wellsites 8		1.2 ha
Truck Trails and Rough Roads	9	10 m
Rural Residential/Cabins	10	Polygon size or 2 ha
Recreational Facilities	11	Polygon size or 2 ha
Borrow Pits	12	Polygon size or 1 ha
Crop/Pasture Land	13	Polygon size
Cutlines, Snowmobile/ATV trails	14	8 m
Power Lines	15	50 m
Pipelines 16		20 m
Recreational Trails (hiking/skiing/biking)	17 4	m
Cutblocks 18		Polygon size
Other Clearings	19	Polygon size

Polygon size[1] - refers to the polygon as provided in the source dataset.
Polygon size or 1 to 4 ha[2] – two source datasets used for this footprint, one in polygon format (ASRD base feature oil and gas plant data) and the second in point format (ERCB small facility point data).

Step 4. Establish a hierarchy for overlapping footprints.

When one land use footprint type overlaps another, for example, a cutline crossing a primary road, the intersect area is classified as one 'dominant' footprint type. A hierarchy was established, which assigns an order of precedence for each of the land use footprint types (Table 4) and was based on the estimated level of activity or use of each footprint. For example, a primary road was assumed to receive more use than a cutline; therefore, the intersect area between the two footprints would be identified as a primary road.

Step 5. Create a single footprint/cleared area layer by combining the individual footprint layers based on the hierarchy.

There are different ways of creating the cleared area layer; however, the hierarchy must always be followed while overlaying the layers. The end result should be a single polygon data layer for each time period (i.e., current and historical) where each polygon is attributed to a specific land use footprint type (e.g., paved road or secondary road). Maintaining data source attributes is also recommended for possible future cross referencing of data.

For the In situ project, the ArcGIS **union** tool was used to create each cleared area layer; it allows use of the hierarchy for ranking layers.

Step 6. Report hectares and percentage of each land use footprint present within the project area or study area(s).

For the project area and each study area, MS Access was used to calculate the cleared area of each land use footprint and the total cleared area for all footprints combined. Also, the percentage of cleared area in each analysis area was calculated.

Prior to conducting the analysis, the cleared area footprint data was attributed with the various study areas, for example each footprint polygon was identified as being located in the Sand or the Jackfish watershed. More detailed information and issues associated with this step include:

Terrestrial vs. aquatic analysis areas: As previously mentioned, the terrestrial analysis area excludes large lakes, while the aquatic analysis area includes all lakes. The terrestrial analysis area was used to report by natural subregion, township, and the overall project area , whereas the aquatic analysis area was used for reporting by watershed. Including or excluding large lakes will affect the proportional importance of the footprint where substantial lake area is present.

Reporting by study area: The method used for the In situ project involved **intersecting** the cleared area layers with the terrestrial and aquatic analysis layers. This resulted in a terrestrial cleared area polygon layer for each time period where each polygon was further divided (if required) by each study area, and attributed with the various study area names and the land use feature type. Similarly, a cleared area polygon layer for the aquatic analysis area were created with each polygon attributed by watershed and by land use feature. Area of each newly created polygon was automatically calculated in the GIS.

Calculations in MS Access: Manipulation of the data in the four resulting cleared area layers using queries in MS Access allowed grouping of data by study area and footprint type so the required calculations could be completed.

Example subregional cleared area analyses for the current and historical time periods for the Central Mixedwood Natural Subregion, Township 64, Range 5, and the Jackfish watershed are provided in Table 5.

Step 7. Visually present Land Use Footprint/cleared area results in maps specific to the project area or study area(s).

The current and historical Land Use Footprints for the In situ project area (i.e., 731.10) are presented in Figure 9 and 10.

Table 5. Example subregional (terrestrial, aquatic, and administrative) Land Use Footprint analyses for the current (~2001) and historical (1981) time periods.

	Central Mixedwood Natural Subregion (NSR)				Township 64, Range 5, W4M				Jackfish Watershed (WS)			
	Historical		Current		Historical		Current		Historical		Current	
	(ha)	% of NSR	(ha)	% of NSR	(ha)	% of Twp.	(ha)	% of Twp.	(ha)	% of WS	(ha)	% of WS
Paved Roads and Highways	0.00	0.00	3.51	0.01	0.00	0.00	0.00	0.00	0.00	0.00	36.30	0.06
Secondary Roads	75.43	0.11	368.58	0.53	12.92	0.14	13.03	0.14	94.31	0.16	309.55	0.54
Truck Trails and Rough Roads	61.66	0.09	75.46	0.11	21.25	0.23	42.35	0.46	89.39	0.16	102.43	0.18
Cutlines, Snowmobile/ ATV trails	558.91	0.80	990.74	1.41	102.21	1.11	192.95	2.09	418.15	0.73	780.76	1.36
Power Lines	32.09	0.05	220.91	0.31	16.11	0.17	24.25	0.26	55.55	0.10	119.19	0.21
Pipelines	9.09	0.01	541.70	0.77	7.00	0.08	29.87	0.32	17.91	0.03	406.53	0.71
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Communities	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.22	0.01	6.22	0.01
Mines and Quarries	0.00	0.00	46.30	0.07	0.00	0.00	11.38	0.12	0.00	0.00	46.30	0.08
Industrial Facilities	39.38	0.06	573.67	0.82	0.26	0.00	0.26	0.00	0.26	0.00	424.14	0.74
Wellsites	178.00	0.25	762.63	1.09	12.10	0.13	29.04	0.31	137.62	0.24	589.22	1.02
Rural Residential/ Cabins	12.79	0.02	18.04	0.03	9.65	0.10	9.65	0.10	63.47	0.11	69.78	0.12
Recreational Facilities	29.40	0.04	35.86	0.05	0.00	0.00	0.00	0.00	2.73	0.00	2.73	0.00
Borrow Pits	2.35	0.00	26.28	0.04	0.00	0.00	8.44	0.09	0.00	0.00	19.58	0.03
Crop/Pasture Land	5,701.47	8.13	7,164.57	10.21	856.03	9.29	1,220.12	13.23	8,475.03	14.74	9,596.93	16.69
Cutblocks	0.00	0.00	424.89	0.61	0.00	0.00	0.00	0.00	0.00	0.00	186.85	0.32
Land Use Footprint TOTAL	**6,700.57**	**9.56**	**11,253.14**	**16.06**	**1,037.53**	**11.25**	**1,581.34**	**17.12**	**9,360.64**	**16.28**	**12,696.51**	**22.07**

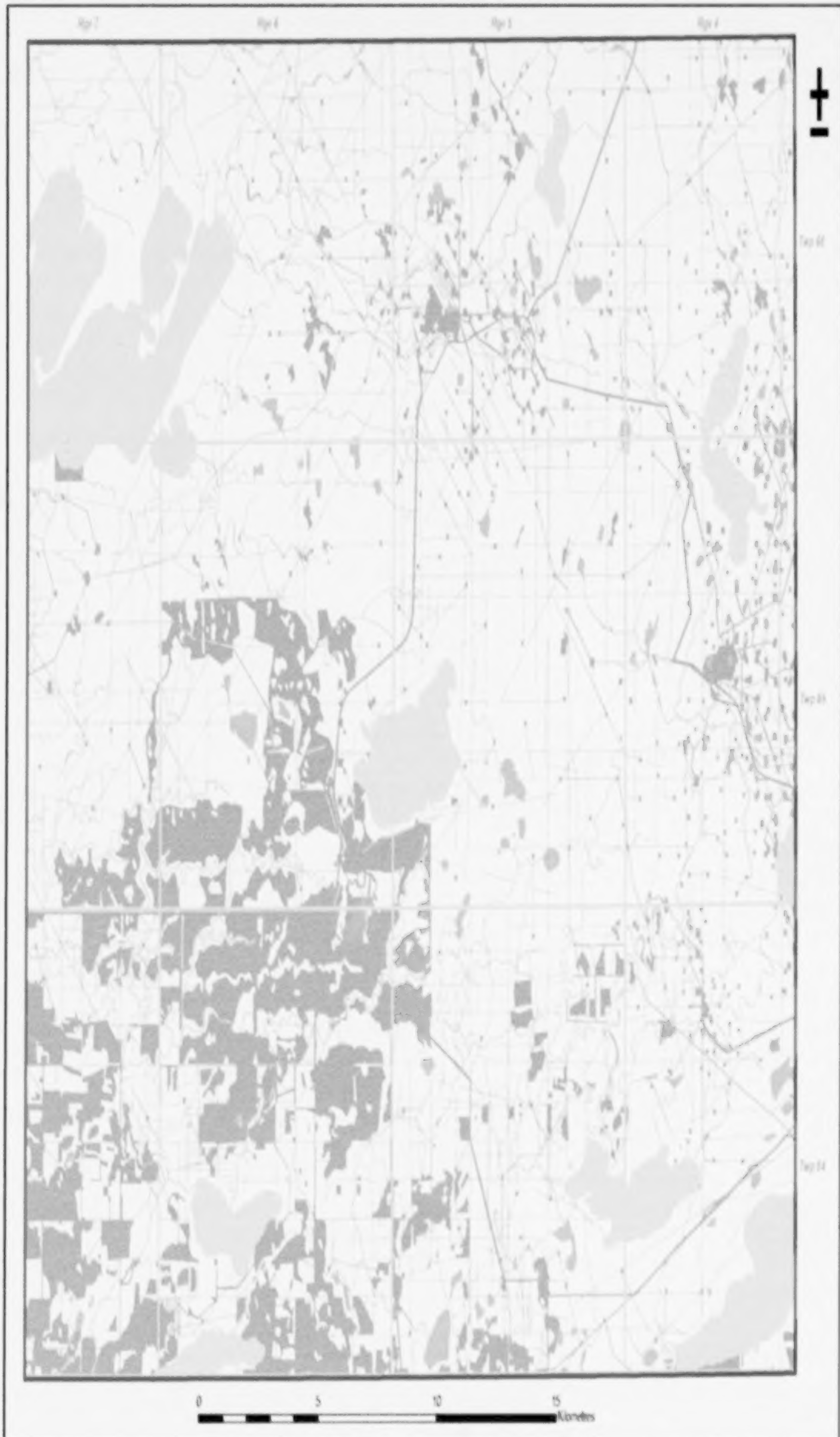

Figure 9

Current Land Use Footprint for the In Situ Project Area (73L10)

Legend

☐	In Situ Footprint Monitoring Pilot Project Area
▨	Land use footprint (Cleared area)
▨	Water body included in project area*
▨	Water body excluded from project area*
—	River
—	Alberta Township System (ATS) grid (W4M)

* Water bodies >100 ha were excluded from the terrestrial analysis area for proportional indicator calculations

Data Sources:

Land use footprint - developed from 1:20 000 Access and Geo-administrative base features (2001), Cadastral data (2007), and Alberta Vegetation Inventory data (2005) provided in digital format by Alberta Sustainable Resource Development, and Energy Resources Conservation Board wellsite and facility data (2008) provided by IHS Energy

Hydrography - 1:20 000 (2000) provided in digital format by Alberta Sustainable Resource Development

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

GIS and cartography on behalf of the ALCES Group by K. Manuel, Salmo Consulting Inc. and M. Sutherland, EcoBorealis Consulting Inc.

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Figure 10

Historical Land Use Footprint for the In Situ Project Area (73L10)

Legend

▢ In Situ Footprint Monitoring Pilot Project Area

▨ Land use footprint (Cleared area)

▨ Water body included in project area*

▨ Water body excluded from project area*

— River

— Alberta Township System (ATS) grid (W4M)

* Water bodies >100 ha were excluded from the terrestrial analysis area for proportional indicator calculations

Data Sources:

Land use footprint - developed from 1:30 000 aerial photography (1961) provided by Alberta Sustainable Resource Development (ASRD) and scanned, orthorectified, and mosaics created by Tarin Resource Services Ltd., used in conjunction with 1:20 000 Access and Geo-administrative base features (2001), Cadastral data (2007), and Alberta Vegetation Inventory data (2005) provided in digital format by ASRD, and Energy Resources Conservation Board website and facility data (2008) provided by IHS Energy

Hydrography - 1:20 000 (2003) provided in digital format by Alberta Sustainable Resource Development

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

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3.3.2 Corridor Density

The Corridor Density indicator quantifies the total length of linear corridors (i.e., highways, roads, railways, pipelines, power lines, seismic lines, cutlines, and trails) per unit area (square kilometre). It was calculated for the project area and study areas using readily available spatial data. Current and historical Corridor Density values were derived by dividing the project area into 1 km by 1 km blocks (i.e., the standard Corridor Density reporting scale) and calculating the length of each linear corridor within each block using GIS analysis. Parallel features were counted individually. This allows the statistical distribution of access within each analysis area to be defined and evaluated if desired.

The steps required to create a dataset to use for calculating Corridor Density are summarized below in Table 6. Information relating to application of each step to the In situ project is also provided.

Table 6. Corridor Density indicator analysis steps.

Step 1	Compile and merge linear feature data.
Step 2	Create a 1 km by 1 km grid over the entire project area.
Step 3	Attribute the 1 km^2 grid blocks with the various study areas.
Step 4	Combine the merged line file with each of the terrestrial and aquatic 1 km^2 grid files.
Step 5	Consider boundary effects.
Step 6	Calculate Corridor Density for each grid block and calculate descriptive statistics (i.e., mean, median, and range values) for the project area or study area(s).
Step 7	Visually present Corridor Density results in maps specific to the project area and study areas.

Step 1. Compile and merge linear feature data.

ASRD access base feature data (i.e., paved roads, secondary roads, truck trails, cutlines, power lines and pipelines) were used to calculate Corridor Density. The separate line data layers were **merged** into a single line layer. More detailed information and issues associated with this step include:

Feature types tracked separately: Fields identifying the data source and feature type were added to the data at this stage in order to allow feature types to be tracked separately once the layers were overlaid.

Integrity of linear features: Typically when dealing with linear features, an effort is made to ensure lines are complete, or are connected to each other, i.e., there is line integrity. Because of the comparatively coarse landscape scale of this monitoring protocol, this level of detail was not considered necessary.

Consideration of parallel features: Merging of the line layers will often result in different linear features paralleling each other in close proximity. Without detailed information (e.g., as-built diagrams), it is impossible to definitively say which features share a right-of-way and which features are in separate corridors. Consequently, all line features are counted individually as corridors, which will overestimate actual Corridor Density.

Step 2. Create a 1 km by 1 km grid over the entire project area.

Corridor Density is reported as the number of kilometres of linear corridor per km^2, where the number of kilometres of each linear feature type and total number of kilometres of all features contained within each 1 km^2 block is calculated. The In situ project area, i.e., map sheet 73L10, is represented by 924 individual 1 km by 1 km grid blocks. More detailed information and issues associated with this step include:

Creation of 1 km^2 grid: Various GIS methods and tools are available to create a grid of 1 km by 1 km polygons (termed grid blocks). It is advantageous to align the grid along at least one side of the project area, which reduces the number of partial blocks along the project boundary edge. If the grid is aligned along two edges, even fewer partial blocks are created, and the 1 km by 1 km blocks are parallelograms rather than square shaped though the area of each is 1 km^2 or 100 ha.

Unique IDs for each 1 km^2 grid block: At this stage, a field was added to the data layer identifying each grid block with a unique ID number in order to allow blocks to be identified when they are divided by study area boundaries in the next step of the protocol.

Step 3. Attribute the 1 km^2 grid blocks with the various study areas.

As Corridor Density is reported for the project area and various study areas (i.e., natural subregion, watershed, township), each 1 km^2 grid block must be attributed with the required study area names. More detailed information and issues associated with this step include:

Reporting by study area: The method used for the In situ project involved intersecting the 1 km^2 grid with the terrestrial and the aquatic analysis layers. This resulted in two new 1 km^2 grid files, one for each of the terrestrial and aquatic study areas. Each block in the terrestrial grid file was identified by subregion, township and mapsheet. Each block in the aquatic 1 km^2 grid was identified by watershed.

Partial grid blocks: Some of the 1 km^2 blocks were split along study area boundaries, including along the map sheet boundary; the result was the creation of partial blocks along boundary edges, for which Corridor Density (i.e., on a km/km^2 basis) must be calculated. The method used to address data contained in these partial blocks is discussed below under 'Consideration of boundary effects'.

Step 4. Combine the merged line file with each of the terrestrial and aquatic 1 km² grid files.

This process essentially re-creates the 1 km² polygon grid layers, but each 1 km² block or partial block is now attributed with the length in kilometres of the various linear features contained within it. Specifically, attributes for each block or partial block include: block ID number, study area names, and the length in kilometres of each linear feature type located in that grid block or portion of a block.

Four Corridor Density grid files were created and include: historical and current terrestrial Corridor Density data, and historical and current aquatic Corridor Density data.

Step 5. Consider boundary effects.

Partial blocks were created along study area boundaries, e.g., a watershed boundary, (the yellow blocks in Figure 11). In addition, in the terrestrial analysis area, where large lakes are excluded, there are partial blocks located along the boundaries of the lakes.

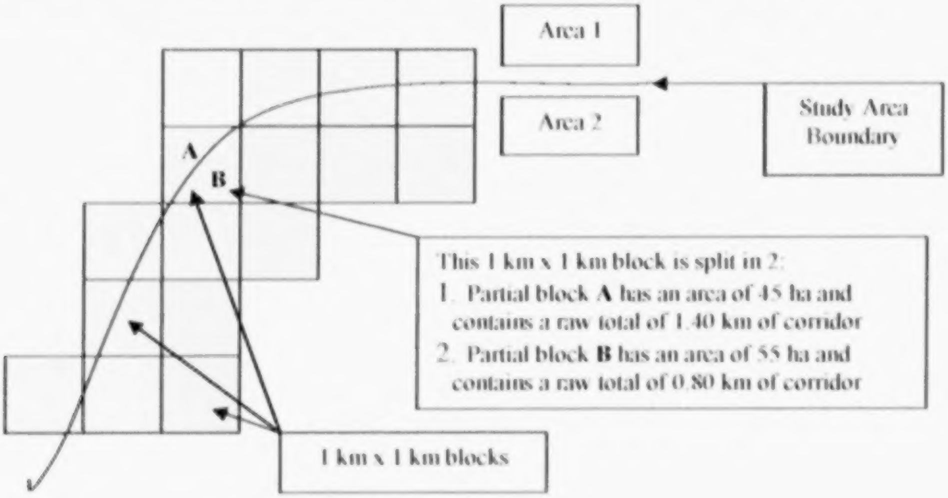
Area 1
Area 2
Study Area Boundary
A
B
This 1 km x 1 km block is split in 2:
1. Partial block A has an area of 45 ha and contains a raw total of 1.40 km of corridor
2. Partial block B has an area of 55 ha and contains a raw total of 0.80 km of corridor
1 km x 1 km blocks

Figure 11 Example of boundary effects.

For the In situ project, three alternate methods of addressing partial block data were used and results compared to identify which method, if any, provides a more accurate representation of the data:

Scaling Up Method: The number of kilometres of each feature and the raw total number of kilometres of all features was calculated in each partial block, and these values were scaled up based on the proportion that each partial block is to a full block. For example, in Figure 11, partial block A would have a scaled up total Corridor Density value of 3.10 km/km², and partial block B a value of 1.45 km/km².

This method can create artificially high maximum values: if a road cuts through a very small partial block, scaling up the data can result in a very high maximum Corridor Density value. This situation may arise in partial blocks along lakes because of the intensive development often located along shorelines. Conversely scaling up could also result in artificially low values, which would tend to balance out average Corridor Density values over the analysis area.

Full Block Method Including Partial Blocks: The number of kilometres of each linear feature and the total linear kilometres in each block that was divided by a boundary was calculated, and these values were used for that grid block in both study areas. For the example in Figure 11 for the block that is split into **A** and **B** – the total Corridor Density of the entire block, 2.20 km/km^2, is used for that block in both study Area 1 and Area 2. This method has implications in terms of data requirements; if this method is used an additional ~1.5 km of data would be required along the boundary of the project area. For the In situ project, additional data, within an approximately 1.5-km band around the 73L10 map sheet, was obtained to support this analysis.

This method essentially changes the predefined boundary of the study area which may not be desirable in some circumstances, e.g., along a watershed boundary.

Full Block Method Excluding Partial Blocks: Only full blocks within the study area were used for this method. Essentially the study area boundary was withdrawn inside to the first full blocks, i.e., the green blocks in Figure 11, and the partial blocks (the yellow blocks) along the boundary were excluded.

Similar to the second method, study area boundaries are altered using this method and this may not be desirable. Also if the study area is very small, excluding boundary data may reduce the number of data points (i.e., effectively reducing the sample size).

Current corridor densities were calculated for both watersheds in the aquatic analysis area (large lakes included) using all three methods. The only partial blocks present were those along the boundary of the watersheds and the map sheet itself. Results are provided in Table 7.

Although no statistical analysis was performed, a simple comparison of the Corridor Density analyses suggests there were no major differences between the three methods with the exception of the maximum range values. Consequently the method adopted for the In situ project protocol was the scaled up method because: 1) boundaries of the study areas are maintained and all the data for each study area is used; 2) the minimum and maximum range values are not a critical component of this analyses because most ecological responses have been related to average or median values; and 3) for future footprint mapping projects, no additional data beyond the study area boundaries would be required.

Step 6. Calculate corridor densities for each grid block and calculate descriptive statistics (i.e., mean, median, and range values) for the project area or study area(s).

Descriptive statistics were calculated using the density of each linear feature and the density of all linear features combined in each grid block or partial block. Queries were run using MS Access, which allowed consolidation of data for the blocks within any chosen study area.

Subregional Corridor Density analyses for the current and historical time periods for the Central Mixedwood Natural Subregion, Township 64, Range 5, and the Jackfish watershed are provided in Table 8. More detailed information associated with this step includes:

Mean vs. Median: A comparison of the mean and median Corridor Density values provides an indication of the distribution of corridors throughout the study area. When these values are similar, it indicates that linear corridors are more evenly distributed throughout the study area. However, in most cases, linear corridor distribution is uneven, and median and average values differ.

Step 7. Visually present Corridor Density results in maps specific to the project area or study area(s).

Current and historical Corridor Densities for the In situ project area (i.e., 73L10) are presented in Figure 12 and 13. For display purposes, Corridor Density values were grouped into discrete ranges (< 0.9 km/km^2; 0.9 km/km^2 to 1.8 km/km^2; >1.8 km/km^2) that can be related to risk of adverse ecological effects (see Section 2.2.2).

Table 7. Comparison of Corridor Density analyses using different methods to account for partial block data.

Jackfish Watershed	Partials Scaled Up				Full Blocks (extended beyond edges)				Full Blocks (no edge partials)			
	Mean (km/km²)	Median (km/km²)	Min. (km/km²)	Max (km/km²)	Mean (km/km²)	Median (km/km²)	Min. (km/km²)	Max (km/km²)	Mean (km/km²)	Median (km/km²)	Min. (km/km²)	Max (km/km²)
Paved Roads and Highways	0.01	0	0	1.26	0.01	0	0	1.26	0.01	0	0	1.26
Secondary Roads	0.29	0	0	5.35	0.28	0	0	4.28	0.28	0	0	4.28
Truck Trails and Rough Roads	0.19	0	0	3.77	0.19	0	0	3.77	0.19	0	0	3.77
Cutlines, Snowmobile / ATV trails	1.89	1.69	0	9.08	1.91	1.72	0	9.08	2.03	1.82	0	9.08
Power Lines	0.1	0	0	2.47	0.11	0	0	1.71	0.11	0	0	1.71
Pipelines	0.56	0	0	12.79	0.53	0	0	5.68	0.52	0	0	5.68
Recreational Trails	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corridor Density TOTAL	**3.04**	**2.8**	**0**	**14.44**	**3.03**	**2.81**	**0**	**11.3**	**3.13**	**2.9**	**0**	**11.3**

Sand Watershed	Partials Scaled Up				Full Blocks (extended beyond edges)				Full Blocks (no edge partials)			
	Mean (km/km²)	Median (km/km²)	Min. (km/km²)	Max (km/km²)	Mean (km/km²)	Median (km/km²)	Min. (km/km²)	Max (km/km²)	Mean (km/km²)	Median (km/km²)	Min. (km/km²)	Max (km/km²)
Paved Roads and Highways	0	0	0	0	0	0	0	0	0	0	0	0
Secondary Roads	0.19	0	0	2.6	0.19	0	0	2.6	0.22	0	0	2.6
Truck Trails and Rough Roads	0.09	0	0	4.17	0.07	0	0	3.13	0.08	0	0	3.13
Cutlines, Snowmobile/ ATV trails	1.61	1.4	0	10.38	1.63	1.46	0	6.78	1.66	1.5	0	6.78
Power Lines	0.09	0	0	2	0.08	0	0	1.59	0.07	0	0	1.59
Pipelines	0.38	0	0	6.75	0.38	0	0	3.77	0.35	0	0	3.77
Recreational Trails	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corridor Density TOTAL	**2.36**	**1.99**	**0**	**17.13**	**2.36**	**2.03**	**0**	**11.56**	**2.38**	**1.99**	**0**	**11.56**

Table 8. Example subregional (terrestrial, aquatic, and administrative) Corridor Density analyses for the current (~2001) and historical (1981) time periods.

	Central Mixedwood Natural Subregion				Township 64, Range 5, W4M				Jackfish Watershed			
	Historical		Current		Historical		Current		Historical		Current	
	Mean (km/km^2)	Median (km/km^2)	Mean (km/km^2)	Median (km/km^2)	Mean (km/km^2)	Median (km/km^2)	Mean (km/km^2)	Median (km/km^2)	Mean (km/km^2)	Median (km/km^2)	Mean (km/km^2)	Median (km/km^2)
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Secondary Roads	0.05	0.00	0.27	0.00	0.08	0.00	0.08	0.00	0.08	0.00	0.29	0.00
Truck Trails and Rough Roads	0.10	0.00	0.13	0.00	0.23	0.00	0.44	0.00	0.16	0.00	0.19	0.00
Cutlines, Snowmobile/ ATV trails	1.04	1.00	1.87	1.72	1.45	1.42	2.84	2.65	1.00	0.95	1.89	1.69
Power Lines	0.01	0.00	0.10	0.00	0.04	0.00	0.15	0.00	0.02	0.00	0.10	0.00
Pipelines	0.01	0.00	0.48	0.00	0.05	0.00	0.29	0.00	0.02	0.00	0.56	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Communities	—	—	—	—	—	—	—	—	—	—	—	—
Mines and Quarries	—	—	—	—	—	—	—	—	—	—	—	—
Industrial Facilities	—	—	—	—	—	—	—	—	—	—	—	—
Wellsites	—	—	—	—	—	—	—	—	—	—	—	—
Rural Residential/ Cabins	—	—	—	—	—	—	—	—	—	—	—	—
Recreational Facilities	—	—	—	—	—	—	—	—	—	—	—	—
Borrow Pits	—	—	—	—	—	—	—	—	—	—	—	—
Crop/Pasture Land	—	—	—	—	—	—	—	—	—	—	—	—
Cutblocks	—	—	—	—	—	—	—	—	—	—	—	—
Corridor Density TOTAL	**1.20**	**1.03**	**2.86**	**2.60**	**1.85**	**2.00**	**3.81**	**3.78**	**1.28**	**1.13**	**3.04**	**2.80**

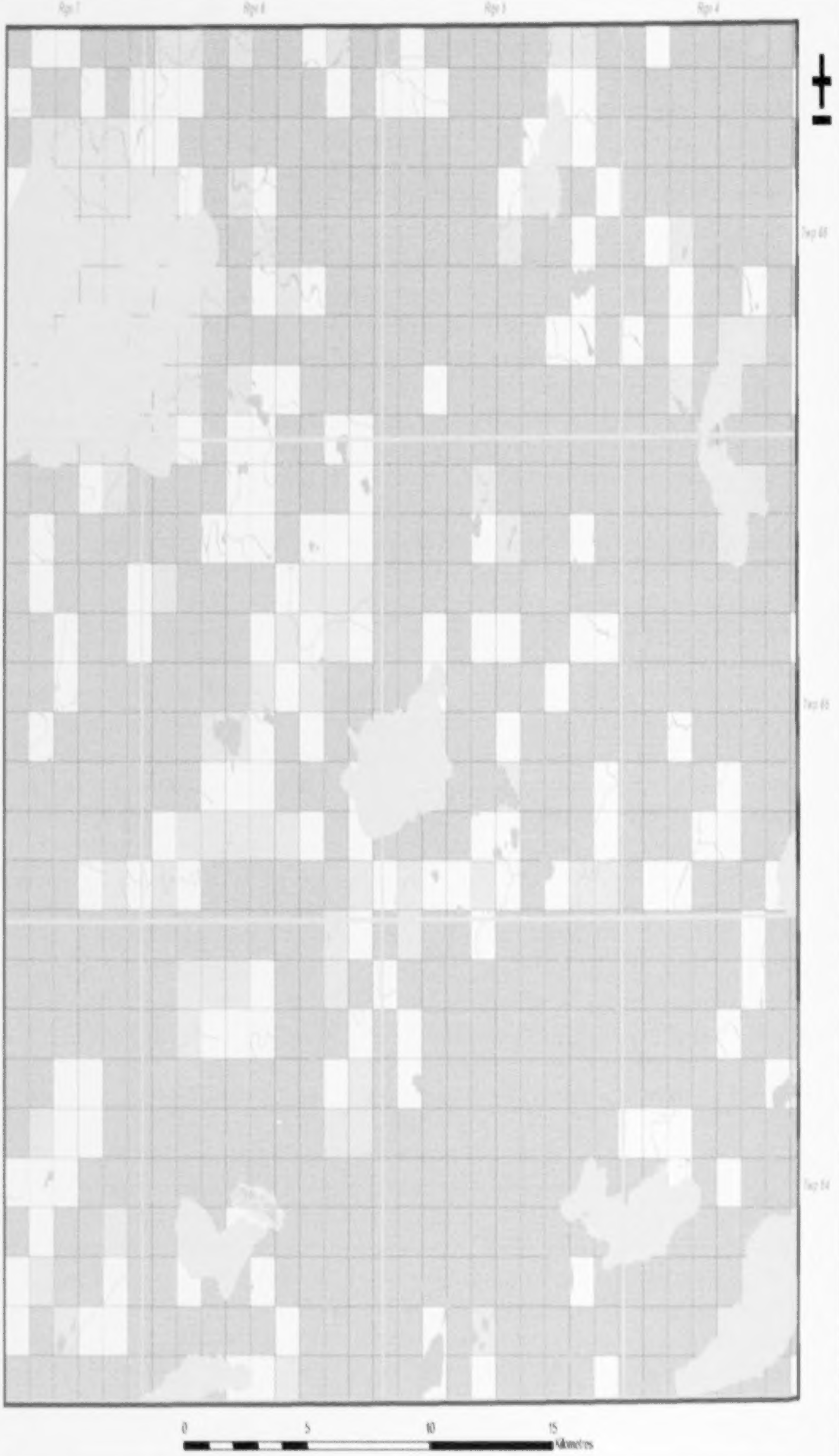

Figure 12

Current Corridor Density for the In Situ Project Area (73L10)

Legend

Corridor Density (km/km^2)

▨	<0.9
□	0.9 - 1.8
▨	>1.8
□	In Situ Footprint Monitoring Pilot Project Area
▨	Water body included in project area*
▨	Water body excluded from project area*
—	River
—	Alberta Township System (ATS) grid (W4M)

* Water bodies >100 ha were excluded from the terrestrial analysis area for proportional indicator calculations

Data Sources:

Corridor density - developed from 1:20 000 Access and Geo-administrative base features (2001), Cadastral data (2007), and Alberta Vegetation Inventory data (2005) provided in digital format by Alberta Sustainable Resource Development, and Energy Resources Conservation Board website and facility data (2008) provided by IHS Energy

Hydrography - 1:20 000 (2000) provided in digital format by Alberta Sustainable Resource Development

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

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Map not suitable for navigation.

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Figure 13

Historical Corridor Density for the In Situ Project Area (73L10)

Legend

Corridor Density (km/km^2)

▨ <0.9

☐ 0.9 - 1.8

▨ >1.8

☐ In Situ Footprint Monitoring Pilot Project Area

▨ Water body included in project area*

▨ Water body excluded from project area*

River

Alberta Township System (ATS) grid (W4M)

* Water bodies >100 ha were excluded from the terrestrial analysis area for proportional indicator calculations

Data Sources:

Corridor density - developed from 1:30 000 aerial photography (1981) provided by Alberta Sustainable Resource Development (ASRD) and scanned, orthorectified, and mosaics created by Tarin Resource Services Ltd., used in conjunction with 1:20 000 Access and Geo-administrative base features (2004), Cadastral data (2007), and Alberta Vegetation Inventory data (2006) provided in digital format by ASRD, and Energy Resources Conservation Board wellsite and facility data (2008) provided by IHS Energy

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3.3.3 Riparian Footprint (Riparian Disturbance)

Riparian disturbance calculations include all forms of surface disturbance that could affect plants, vegetation communities, wildlife habitat, aquatic ecosystems, and visual values or human use. For the In situ project area, this direct footprint indicator was calculated for the project area, major drainages, natural subregions, and individual townships.

Riparian and wetland disturbance was calculated using hydrography and wetland inventory data available for the project area. The width of the **riparian zone** varies with stream and waterbody size and valley/basin characteristics. Riparian buffers adopted for streams, waterbodies, and wetlands in the in situ study area were reasonable averages based on Forestry Operating Ground Rule (AENV 1994) buffer restrictions of 30 m for small permanent streams and wetlands, 60 m on large permanent rivers and lakes less than 4 ha in area, and 100 m on lakes greater than or equal to 4 ha in area.

The steps required to create a dataset to use for calculating the Riparian Footprint are provided below in Table 9. Information relating to application of the each step to the In situ project is also provided.

Table 9. Riparian Footprint indicator analysis steps.

Step 1	Compile stream, wetland, and lake data for the project area
Step 2	Create a riparian zone layer.
Step 3	Isolate the direct land use footprint located within the riparian zone of the project area or study area(s).
Step 4	Report hectares and percent of Riparian Footprint / disturbance.
Step 5	Visually present Riparian Footprint results in maps specific to the project area and each study area.

Step 1. Compile stream, wetland and lake data for the project area.

Line and polygon hydro data are included in the ASRD base features data and were used for this indicator. Line data are a connected network of single line hydrography and includes lines through hydro polygons. The polygon dataset is a representation of large areas of surface hydrography, and can include widened sections of streams, rivers, as well as lakes.

Wetland data are not as easily accessible, but a wetland classification can be created using the AVI dataset, which may be available through ASRD or FMA holders. Another source is through the Earth Observation for Sustainable Development of Forests land cover mapping project, which is based on Landsat 7 imagery. More detailed information associated with this step includes:

Wetland data obtained from the AVI dataset: The vegetated land in the AVI dataset is further characterized by moisture regime modifiers. Wetland areas were selected based on a moisture regime of wet or aquatic, which included areas of permanent water, to those poorly drained to flooded with the water table near the surface.

Step 2. Create a riparian zone layer.

Hydrography and wetland data were buffered according to the standard riparian width estimates for the project area. More detailed information and issues associated with this step include:

Riparian buffers for hydrography and wetland data: For the In situ project, the stream line file was buffered by 30 m – a review of the project area suggests there are no large permanent rivers present which would require a 60 m buffer. Wetlands were buffered by 30 m, and lakes by 60 or 100 m depending on the lake size.

Combined riparian zone layer: The riparian zone layer was created by first merging the three buffered layers, then **dissolving** the boundaries between the different buffers, and lastly, lakes were removed from this layer as they are not part of the riparian zone.

Riparian footprint/disturbance: Attribute any footprint or disturbance located within the riparian zone.

Step 3. Isolate the direct land use footprint located within the riparian zone of the project area or study area(s).

The terrestrial and aquatic cleared area layers developed for the cleared area footprint analysis were used in this step. Each layer was intersected with the riparian zone layer. Essentially, layers were created that showed polygons of cleared area or land use disturbance present in the riparian zone. These polygons of cleared area within the riparian zone are called riparian footprint or disturbance. More detailed information and issues associated with this step include:

Isolating the land use footprint within the riparian zone of each study area: The cleared area footprint layers were attributed to the various study areas. Each cleared area footprint layer and the riparian zone layer then were intersected in the GIS, resulting in a layer that contained land use footprint polygons located within the riparian zone, with each polygon identified by land use feature type and study area. The following two layers were created for each time period (i.e., current and historical):

(a) Riparian disturbance within terrestrial analysis area: each polygon of riparian disturbance was identified by land use feature type and study area (i.e., natural subregion and township), and

(b) Riparian disturbance within aquatic analysis area: each polygon of riparian disturbance was identified by land use feature type and watershed.

Step 4. Report hectares and percent of Riparian Footprint/disturbance.

The hectares and percentage of riparian disturbance, listed by land use feature type, within each study area were determined. The percentage values were based on percent of riparian disturbance within the riparian zone of a study area. Descriptive statistics were calculated in MS Access, allowing consolidation of riparian disturbance by feature type and study area.

Subregional riparian disturbance analyses for the current and historical time periods for the Central Mixedwood Natural Subregion, Township 64, Range 5, and the Jackfish watershed are provided in Table 10. More detailed information associated with this step includes:

Determined the area of riparian zone located within the project area or study area(s): These data are required to determine the percentage of riparian area (in each study area) affected by land use footprint. The riparian zone layer was intersected with the terrestrial and aquatic study area layers used in the Land Use Footprint cleared area analysis. The resulting terrestrial-riparian zone layer provided data on the area of riparian zone within each natural subregion, township and the project area. Similarly the aquatic – riparian zone layer provided data on the hectares of riparian zone in each watershed.

Step 5. Visually present riparian disturbance results in maps specific to the project area and each study area.

Riparian footprint results for the In situ project area (i.e., 73L10) are presented in Figures 14 and 15.

Table 10 Example subregional (terrestrial, aquatic, and administrative) Riparian Footprint analyses for the current (~2001) and historical (1981) time periods

	Central Mixedwood Natural Subregion				Township 64, Range 5, W4M				Jackfish Watershed			
	Historical		Current		Historical		Current		Historical		Current	
	(ha)	% of Riparian Zone	(ha)	% of Riparian Zone	(ha)	% of Riparian Zone	(ha)	% of Riparian Zone	(ha)	% of Riparian Zone	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.48	0.03
Secondary Roads	11.13	0.04	73.95	0.25	2.81	0.09	2.81	0.09	16.76	0.08	60.15	0.30
Truck Trails and Rough Roads	9.44	0.03	12.64	0.04	4.94	0.16	8.02	0.26	17.41	0.09	16.93	0.08
Cutlines, Snowmobile/ ATV trails	231.05	0.77	465.59	1.55	27.49	0.88	65.37	2.09	152.51	0.75	331.48	1.63
Power Lines	1.86	0.01	43.31	0.14	7.80	0.25	10.26	0.33	10.06	0.05	27.00	0.13
Pipelines	0.48	0.00	194.20	0.65	5.66	0.18	12.16	0.39	6.64	0.03	153.09	0.75
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Communities	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.54	0.03	5.54	0.03
Mines and Quarries	0.00	0.00	11.33	0.04	0.00	0.00	2.81	0.09	0.00	0.00	11.33	0.06
Industrial Facilities	1.11	0.00	189.56	0.63	0.19	0.01	0.19	0.01	0.19	0.00	142.02	0.70
Wellsites	47.27	0.16	231.19	0.77	1.58	0.05	8.84	0.28	36.12	0.18	163.32	0.80
Rural Residential/ Cabins	1.22	0.00	1.22	0.00	0.15	0.00	0.15	0.00	11.52	0.06	11.52	0.06
Recreational Facilities	10.06	0.03	15.60	0.05	0.00	0.00	0.00	0.00	2.07	0.01	2.07	0.01
Borrow Pits	0.00	0.00	2.58	0.01	0.00	0.00	0.48	0.02	0.00	0.00	1.86	0.01
Crop/Pasture Land	224.30	0.75	275.87	0.92	91.05	2.91	124.67	3.98	534.10	2.62	600.74	2.95
Cutblocks	0.00	0.00	66.06	0.22	0.00	0.00	0.00	0.00	0.00	0.00	28.10	0.14
Riparian Footprint TOTAL	**537.92**	**1.79**	**1,583.10**	**5.27**	**141.67**	**4.53**	**235.76**	**7.54**	**792.92**	**3.90**	**1,560.63**	**7.68**

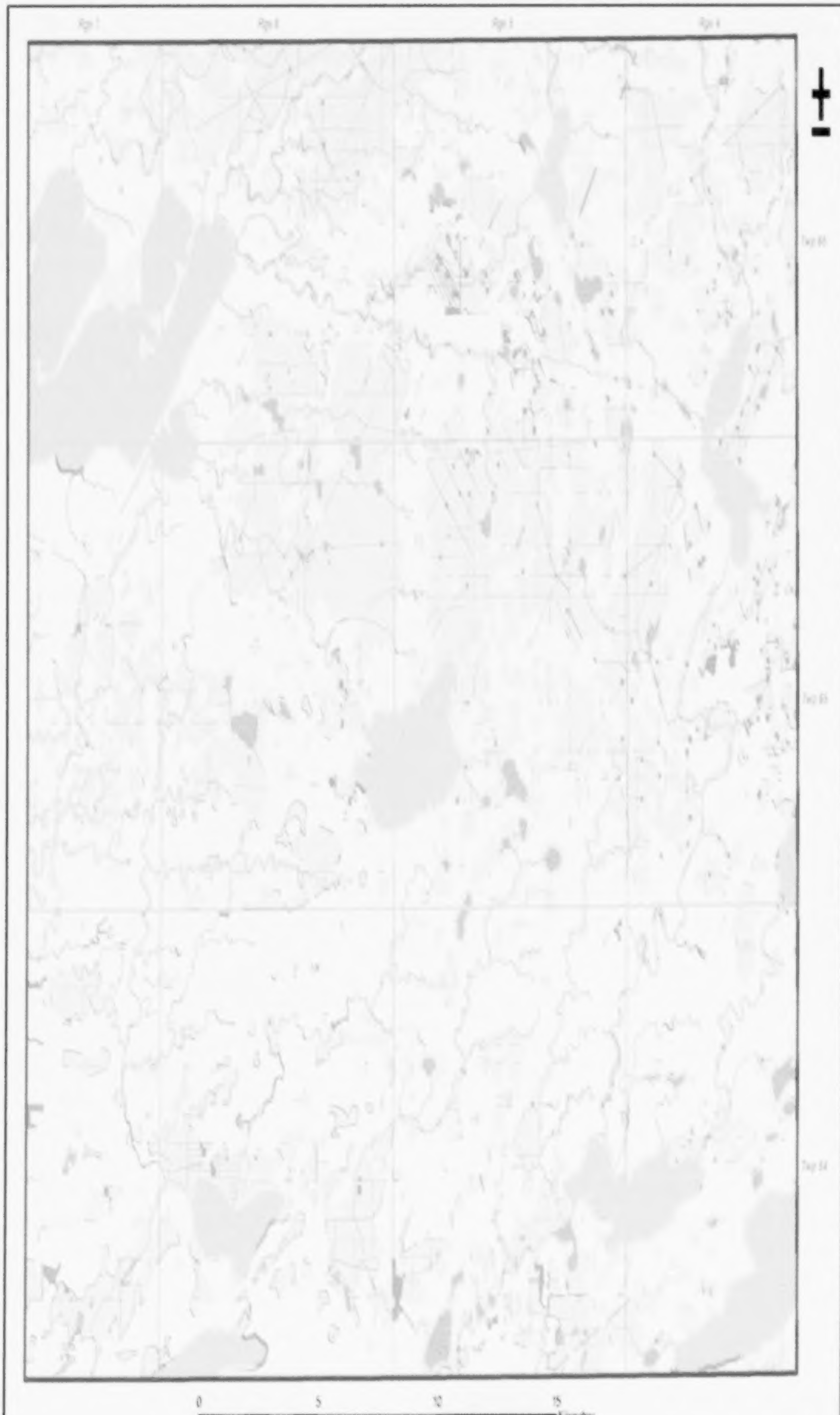

Figure 14

Current Riparian Footprint Present in the In Situ Project Area (73L10)

Legend

☐	In Situ Footprint Monitoring Pilot Project Area
▨	Riparian footprint
☐	Riparian zone
▨	Water body included in project area*
▨	Water body excluded from project area*
—	River
—	Alberta Township System (ATS) grid (W4M)

* Water bodies >100 ha were excluded from the terrestrial analysis area for proportional indicator calculations

Data Sources:

Riparian footprint - developed from 1:20 000 Access and Geo-administrative base features (2007), Cadastral data (2007), and Alberta Vegetation Inventory data (2005) provided in digital format by Alberta Sustainable Resource Development, and Energy Resources Conservation Board wellsite and facility data (2008) provided by IHS Energy

Riparian zone - developed from 1:20 000 Alberta Vegetation Inventory data (2005) provided in digital format by Alberta Sustainable Resource Development

Hydrography - 1:20 000 (2000) provided in digital format by Alberta Sustainable Resource Development

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

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Figure 15

Historical Riparian Footprint Present in the In Situ Project Area (73L10)

Legend

- ☐ In Situ Footprint Monitoring Pilot Project Area
- ▨ Riparian footprint
- ☐ Riparian zone
- ▨ Water body included in project area*
- ▨ Water body excluded from project area*
- — River
- — Alberta Township System (ATS) grid (W4M)

* Water bodies >100 ha were excluded from the terrestrial analysis area for proportional indicator calculations

Data Sources:

Riparian footprint - developed from 1:30 000 aerial photography (1961) provided by Alberta Sustainable Resource Development (ASRD) and scanned, orthorectified, and mosaics created by Tarin Resource Services Ltd., used in conjunction with 1:20 000 Access and Geo-administrative base features (2001), Cadastral data (2007), and Alberta Vegetation Inventory data (2006) provided in digital format by ASRD; and Energy Resources Conservation Board wellsite and facility data (2008) provided by IHS Energy

Riparian zone - developed from 1:20 000 Alberta Vegetation Inventory data (2005) provided in digital format by Alberta Sustainable Resource Development

Hydrography - 1:20 000 (2000) provided in digital format by Alberta Sustainable Resource Development

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

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3.3.4 Core Area

Relatively undisturbed core areas are found beyond a zone-of-influence or 'indirect footprint" immediately adjacent to man-made features. Core Area was calculated for both the current and historical time periods for the project area and study areas (natural subregions, major drainages, and individual townships). The number and size of residual core areas in each of these analysis areas also was noted. This supports statistical analyses and comparison to species home range size (e.g., most residual core areas are smaller than the home range of species X, and are therefore considered to be unusable for this species).

The steps required to create a dataset to use for calculating Core Area are provided below in Table 11. Information relating to application of the each step to the In situ project is also provided.

Table 11. Core Area indicator analysis steps.

Step 1	Apply the 200 m zone of influence buffer (rationale in Section 2.2.4) around all footprints in the Land Use Footprint cleared area layers.
Step 2	Isolate and track each core area separately.
Step 3	Report Core Area including total hectares, percent of analysis area, number of core areas, the median core area, and the range in size of core areas.
Step 4	Visually present Core Area results in maps specific to the project area or study areas.

Step 1. Apply the 200 m zone of influence buffer around all footprints in the Land Use Footprint cleared area layers.

Similar to the riparian disturbance analysis, the terrestrial and aquatic cleared area layers were included as input in this step. A buffer of 200 m was applied to all cleared areas.Core area is reported as the area outside the cleared area and the 200 m zone of influence. More detailed information and issues associated with this step include:

Dissolve boundaries: Boundaries were dissolved in the GIS so that the cleared area and zone of influence were combined.

Wolf Lake Forest Recreation Trail: ASRD base features data provided a polygon feature surrounding Wolf Lake; but a specific line feature showing the location of the trail was not available. This polygon area was assumed to encompass the cleared area and the area of influence associated with the Wolf Lake Trail. The Wolf Lake polygon was combined with the main cleared area/area of influence layer (for the current scenario only).

Species-specific Core Area reporting: As noted in Section 2.2.4, different species may be impacted by footprints and human activity in different ways and thus the buffer applied to land use features can be changed to consider cumulative effects on individual species. For example, if the area of influence buffer was changed to 500 m, the resulting core statistics would be particularly relevant to grizzly bears.

Step 2. Isolate and track each core area separately.

Essentially the cleared area and the area of influence were removed from the terrestrial and aquatic analysis layers. The resulting polygons are core areas and are quantified individually. Four core area files were created: terrestrial and aquatic core area files for the current and historical time periods. More detailed information and issues associated with this step include:

Terrestrial vs. aquatic core areas: The core files for the watershed study areas included large lakes which are included as core areas. These aquatic core areas are not counted in the township and natural region study areas where the large lakes were excluded because they have no value for terrestrial species.

Isolate the core areas: Through a series of GIS steps, the core areas were isolated and tracked individually for each of the four core layers. Each core area polygon was attributed by study area; for example, the core area in terrestrial study area would be split by natural subregion and township.

Step 3. Report Core Area including total hectares, % of analysis area, number of core areas, the median core area, and the range in size of core areas.

Descriptive statistics were calculated in MS Access to provide additional information on the attributes of core areas within the project and study areas.

Subregional Core Area analyses for the current and historical time periods for the Central Mixedwood Natural Subregion, Township 65, Range 4, and the Jackfish watershed are provided in Table 12. More detailed information and issues associated with this step include:

Consideration of boundary effects: A core area that occurs along the boundary of a study area is split and each portion of core is reported for the respective study area. This 'boundary effect' will impact results by reducing the size of core areas along boundaries. Reporting of core using the largest study area would result in the least number of 'boundary effects'. For the In situ project, core reported for the project area, 731,10, using the aquatic analysis area (with all lakes included) would have no artificially created core area splits (except for those core areas that extend outside the project area).

Table 12 Example subregional (terrestrial, aquatic, and administrative) Core Area analyses for the current (~2001) and historical (1981) time periods.

	Total		No. of Core Areas	Median Size (ha)	Core Area Size Range (ha)	
	(ha)	% of Study Area Min				Max
Central Mixedwood Natural Subregion						
Historical	35,741.93	50.95	235	15.46	<0.01	2,607.85
Current	13,635.35	19.44	614	4.21	<0.01	579.17
Township 64, Range 5, W4M						
Historical	3,107.47	33.71	53	13.57	<0.01	958.7
Current	906.91	9.84	93	2.45	<0.01	162.51
Jackfish Watershed (WS)						
Historical	24,353.22	42.35	193	16.16	<0.01	2,251.84
Current	9,326.02	16.22	438	4.11	<0.01	892.91

Step 4. Visually present Core Area results in maps specific to the project area and study areas.

Current and historical Core Area results for the In situ project area (i.e., 731.10) are presented in Figure 16 and 17.

Figure 16

Current Core Area Results for the In Situ Project Area (73L10)

Legend

☐	In Situ Footprint Monitoring Pilot Project Area
▨	Core area
▨	Water body included in project area*
▨	Water body excluded from project area*
—	River
—	Alberta Township System (ATS) grid (W4M)

* Water bodies >100 ha were excluded from the terrestrial analysis area for proportional indicator calculations

Data Sources:

Core area - developed from 1:20 000 Access and Geoadministrative base features (2001), Cadastral data (2007), and Alberta Vegetation Inventory data (2005) provided in digital format by Alberta Sustainable Resource Development, and Energy Resources Conservation Board website and facility data (2008) provided by IHS Energy

Hydrography - 1:20 000 (2000) provided in digital format by Alberta Sustainable Resource Development

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

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Figure 17

Historical Core Area Results for the In Situ Project Area (73L10)

Legend

▭ In Situ Footprint Monitoring Pilot Project Area

▨ Core area

▨ Water body included in project area*

▨ Water body excluded from project area*

— River

— Alberta Township System (ATS) grid (W4M)

* Water bodies >100 ha were excluded from the terrestrial analysis area for proportional indicator calculations

Data Sources:

Core area - developed from 1:30 000 aerial photography (1981) provided by Alberta Sustainable Resource Development (ASRD) and scanned, orthorectified, and mosaics created by Tarin Resource Services Ltd., used in conjunction with 1:20 000 Access and Geo-administrative base features (2001), Cadastral data (2007), and Alberta Vegetation Inventory data (2005) provided in digital format by ASRD, and Energy Resources Conservation Board wellsite and facility data (2008) provided by IHS Energy

Hydrography - 1:20 000 (2000) provided in digital format by Alberta Sustainable Resource Development

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

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3.3.5 Certified Footprint

The Certified Footprint indicator quantifies areas where active human land use has been discontinued and the decision of a land manager indicates that certification criteria are met (i.e., Reclamation Certificate has been issued). AENV provided a list of pipelines and temporary workspace, wellsites, and access roads located in the project area that received Reclamation Certificates. The list provided only general location references (i.e., to the quarter section only), with the exception of wells which included a legal description down to Legal Subdivision (LSD). Only certified wellsites could be linked to a specific footprint in the project area.

The project team was provided with detailed Conservation and Reclamation information and digital files prepared by Imperial Oil Resources Ltd. (Imperial), an in situ operator thought to be providing the most complete reclamation data to AENV. These conservation and reclamation data include digital, geo-referenced shape files that document actual (i.e., 'as-built') footprint location and size, as well as reclamation objectives (e.g., Natural Reclamation or Forest Reclamation). However, Certification status was not reported, and Certified Footprint could not be calculated.

For the reasons described above, the Certified Footprint Indicator was calculated for wellsites only in the project area (73L10), and study areas (natural subregions, major drainages, and individual townships). These data inconsistencies resulted in an underestimation of the Certified Footprint.

The steps required to create a dataset to use for calculating the certified footprint are provided below in Table 13. Information relating to application of the each step to the In situ project is also provided.

Table 13 Certified Footprint indicator analysis steps

Step 1	Assign Certified status to cleared area footprints.
Step 2	Certified Footprint reporting.
Step 3	Visually present Certified Footprint results in maps specific to the project and each study area.

Step 1. Assign Certified status to cleared area footprints.

This step involved cross referencing well names from the AENV Reclamation Certificate list and operator Conservation and Reclamation data with well name information in the ERCB well list. The ERCB well list, and specifically those wells that have been Certified, were then spatially linked to footprints in the cleared area layers (developed for the cleared area Land Use Footprint indicator). More detailed information and issues associated with this step include:

Cross-referencing well names: The cross-referencing of well names between the two datasets (i.e., AENV reclamation list and ERCB well list) was an onerous process as it had to be done manually; there was no way to combine the data automatically because of differences in data referencing. Once the cross-referencing process was completed, the ERCB well list was attributed with an additional column indicating Reclamation Certificate status.

Certified wells on ERCB well list linked to a wellsite cleared area footprint: As indicated under the cleared area protocol, each well in the ERCB data set was assigned a 1.2 ha footprint, which resulted in overlapping footprints where wells were drilled in close proximity to each other or from the same lease. Consequently a footprint could be associated with the data from one to many wells. Footprints from the cleared area layer that coincided with a certified well status from the ERCB data were assigned a certified status.

Other reclamation certificate data sources: It is possible that there is a different and more useable source of Reclamation Certificate information than used here, that could have made the above process easier. However, the end result must provide Reclamation Certificate status linked to a specific spatial footprint with a defined area.

Step 2. Certified Footprint reporting.

Certified Footprint results were reported as total hectares within the respective project or study area and as proportions of the project or study area. Again, queries were run in MS Access to compile certified footprints for the project and study areas.

Subregional Certified Footprint analyses for the current time period for the Central Mixedwood Natural Subregion, Township 65, Range 4, and the Jackfish watershed are provided in Table 14. Issues associated with this step include:

Overlapping footprints: The footprint reporting as described does not take into account whether another land use disturbance has occurred on the certified site. For example, a certified wellsite may have been later redeveloped as an oil and gas facility, and thus would now be considered active. Disjointed tracking across regulators and resource managers responsible for different activities on the same land base prevents accurate tracking of what is actually happening on the land.

Step 3. Visually present Certified Footprint results in maps specific to the project area and each study area.

Certified Footprints in the In situ project area are shown on Figures 18 and 19.

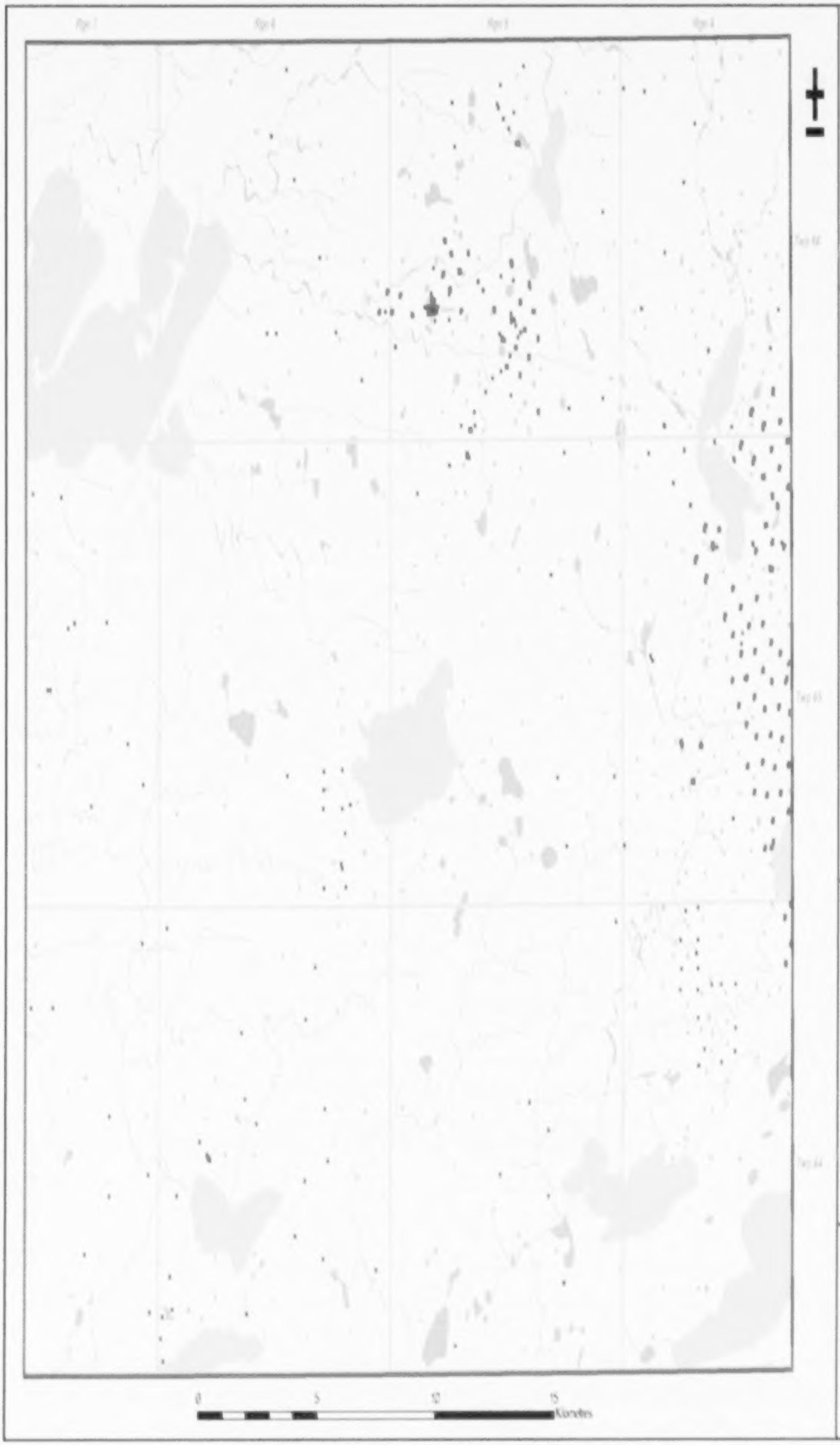

Figure 18

Current Certified and Inactive Footprints Results for the In Situ Project Area (73L10)

Legend

- ☐ In Situ Footprint Monitoring Pilot Project Area
- ▨ Certified footprint - wellsite
- ▨ Inactive footprint - wellsite (abandoned or dry hole)
- ■ Other wellsite
- ▨ Water body included in project area*
- ▨ Water body excluded from project area*
- — River
- — Alberta Township System (ATS) grid (W4M)

* Water bodies > 100 ha were excluded from the terrestrial analysis area for proportional indicator calculations

Data Sources:

Certified footprint - developed from Energy Resources Conservation Board wellsite data (2008) provided in digital format by IHS Energy and from a list of reclamation certificates issued (2008) provided by Alberta Environment

Inactive footprint - developed from Energy Resources Conservation Board wellsite data (2008) provided in digital format by IHS Energy

Hydrography - 1:20 000 (2000) provided in digital format by Alberta Sustainable Resource Development

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

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Figure 19

Historical Certified Footprint Results for the In Situ Project Area (73L10)

Legend

☐	In Situ Footprint Monitoring Pilot Project Area
▨	Certified footprint - wellsite
■	Other wellsite (may be active or inactive)
▨	Water body included in project area*
▨	Water body excluded from project area*
—	River
—	Alberta Township System (ATS) grid (W4M)

* Water bodies >100 ha were excluded from the terrestrial analysis area for proportional indicator calculations.

Data Sources

Certified footprint - developed from 1:30 000 aerial photography (1981) provided by Alberta Sustainable Resource Development and scanned, orthorectified, and mosaics created by Tanir Resource Services Ltd., used in conjunction with Energy Resources Conservation Board wellsite data (2008) provided in digital format by IHS Energy and from a list of reclamation certificates issued (2008) provided by Alberta Environment.

Hydrography - 1:20 000 (2003) provided in digital format by Alberta Sustainable Resource Development.

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

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Table 14. Example subregional (terrestrial, aquatic, and administrative) Certified Footprint analyses for the current (~2001) time period.

Study Area	Certified Wells (ha)	% of Study Area
Central Mixedwood Natural Subregion	25.30 0.04	
Township 64, Range 5	14.52	0.16
Jackfish Watershed	51.35	0.09

3.3.6 Inactive Footprint

The Inactive Footprint indicator quantifies areas where active human land use has been discontinued but the site has not yet been reclaimed or restored. The only data that provided attributes as to site operational status that could be used for the Inactive Footprint indicator, e.g., active versus not active, was the ERCB well data obtained from the third party distributor IHS Energy. Consequently the Inactive Footprint indicator was calculated for wellsites only, for the current time period and all study areas. In the absence of specific information, abandoned wells and dry holes that did not have a Reclamation Certificate were considered inactive for this pilot project.

The steps required to create a dataset for use in calculating the Inactive Footprint are provided below in Table 15. Information relating to application of the each step to the In situ project is also provided.

Table 15. Inactive Footprint indicator analysis steps

Step 1	Assign Inactive status to wellsite footprints.
Step 2	Inactive Footprint reporting.
Step 3	Visually present Inactive Footprint results in maps specific to the project area and each study area.

Step 1. Assign an inactive status to wellsite footprints.

As mentioned previously, ERCB well data are the basis of the well footprint created in the cleared area analysis. These well data include information such as well name and operational status, e.g., suspended, abandoned. A similar process to that carried out in Step 1 of the Certified Footprint was carried out here. Wells on the ERCB list with and abandoned or dry hole status, were spatially linked to a footprint on the cleared area layers, and these footprints were assigned an inactive status.

Step 2. Inactive footprint reporting.

Inactive wellsite footprints that have not received a Reclamation Certificate were reported as total hectares within the respective study areas and as a proportion of the study area. This step involved excluding well footprints assigned a Certified status (Certified Footprint Indicator process) from the inactive footprint determined in Step 1 of this indicator. MS Access was used to calculate the results.

Subregional inactive footprint analyses for the current time period for the Central Mixedwood Natural Subregion, Township 65, Range 4, and the Jackfish watershed are provided in Table 16. Issues associated with this step include:

Overlapping footprints: The same issue applies here regarding whether another land use disturbance has occurred on a wellsite and thus changing its status. Disjointed tracking across jurisdictions for the same land base prevents any understanding of what is actually happening on the land.

Step 3. Visually present inactive footprint results in maps specific to the project area and each study area.

Current inactive footprint results for the In situ project area (731.10) are shown on Figure 18.

Table 16. Example subregional (terrestrial, aquatic, and administrative) inactive footprint analyses for the current (~2001) time period.

Study Area	Inactive Wells (ha)	% of Study Area
Central Mixedwood Natural Subregion	395.98 0.56	
Township 64, Range 5	6.05	0.07
Jackfish Watershed	271.64	0.47

3.3.7 Restored Footprint

The Restored Footprint indicator quantifies areas where a self-sustaining native vegetation community has been returned to disturbed sites and corridors, and a Reclamation Certificate has been issued where required.

Information to generate Restored Footprint indicator estimates was not available for the In situ project area, as discussed below.

- Forestry cutblock data may provide an indication of restored footprint, i.e., if a cutblock was assigned 'free to grow' status. However this information was not available for the In situ project.
- With respect to oil and gas activity, Green Area reclamation direction has just recently changed suggesting that over time, reclaimed and certified oil and gas sites should meet restored footprint indicator standards. However, at the current time no sites appear to meet these criteria.
- White Area reclamation standards for permanently grassed areas(e.g., native prairie) recommend use of native species and once reclaimed these areas may meet restored footprint indicator standards. However, for the In situ area no information was located to indicate that a wellsite in the White Area was restored to a self-sustaining native vegetation community.

In order to complete this analysis, reclamation or silvicultural records that indicate the vegetation status of a site must be linked to a spatially explicit footprint. Data requirements include the type of vegetation, growth stage (e.g., free to grow), and reclamation certificate status.

Imperial Conservation and Reclamation map data included reclamation objectives (e.g., Natural Reclamation or Forest Reclamation), but not reclamation status relative to these objectives, and Restored Footprint could not be calculated.

If the required reclamation/silvicultural data linked to spatially explicit footprint were available, the steps required to create a dataset for use in calculating the restored footprint are provided below in Table 17.

Table 17. Restored Footprint indicator analysis steps.

Step 1	Determine which footprints in the Green Area have been issued a Reclamation Certificate as per the recent AENV guideline which identifies forest ecosystems as the desired reclamation outcome for Green Area oil and gas sites (AENV 2007b).
Step 2	Determine which cutblock footprints have reached 'free to grow' status.
Step 3	Determine which oil and gas footprints in the White Area have been reclaimed to a native ecosystem, for example native prairie, and a reclamation certificate issued.
Step 4	Compile the Green and White Area restored footprint data, and report on a study area basis the total hectares restored and percent of each study area restored.
Step 5	Visually present Restored Footprint results in maps specific to the project area or study area(s).

3.3.8 Net Footprint

Net Footprint represents the Land Use Footprint less Restored Footprint for each analysis area. Because Restored Footprint could not be estimated due to lack of data, Net Footprint must be assumed to be equal to the Land Use Footprint in the In situ project area.

If the required Restored Footprint data were available, the steps required to create a dataset to calculate Net Footprint are provided below in Table 18.

Table 18. **Net Footprint indicator analysis steps.**

Step 1	Obtain the current total Land Use Footprint / cleared area (ha) for each study area (Section 3.3.1).
Step 2	Obtain the restored footprint (ha) for each study area (Section 3.3.7).
Step 3	For each study area, subtract the hectares of restored footprint from the total hectares of land use footprint; the result is the net footprint per study area.
Step 4	Visually present Net Footprint results in maps specific to the project area or study area(s).

For the In situ project area, the Net footprint would be equivalent to the Land Use Footprint indicator results. Example subregional Land Use Footprint analyses for the current period for the Central Mixedwood Natural Subregion, Township 64, Range 5, and the Jackfish watershed were provided earlier in Table 5.

4. CONCLUSIONS AND RECOMMENDATIONS

A suite of eight generalized disturbance and reclamation indicators was adopted for the In situ project area to fulfill AENV's mandate and provide information for integrated decision making and management (Table 1; Sections 2.2.1 through 2.2.8). The key selection criterion used was that indicators must allow the effects of both in situ and combined footprints to be evaluated and differentiated. Additional selection criteria included the need to: 1) support existing management and decision making structures; 2) be practical to implement; and 3) be scientifically defensible.

The four disturbance indicators (Land Use Footprint; Corridor Density, Riparian Footprint, and Core Area) provide information about combined direct and indirect land use footprints that can be used to evaluate terrestrial and aquatic cumulative effects risks. These indicators can also be linked to management thresholds to ensure that desired provincial, regional, and sub-regional ecological and social outcomes are achieved.

The three reclamation indicators (Certified Footprint, Inactive Footprint, and Restored Footprint) quantify how much footprint has been or could be reclaimed as well as its reclamation status relative to natural (pre-disturbance) landscape conditions.

The Net Footprint indicator combines disturbance and reclamation indicators to provide a simple measure of combined footprint less the area that has been restored to natural conditions (i.e., Net Footprint = Land Use Footprint – Restored Footprint).

Accurate, timely, and accessible information is essential to good planning and decision-making (ASRD 2008). The indicator monitoring protocols provided in Section 3 are based on the use of existing, readily available data collected by regulators and resource managers. As described further below, while readily available data do not provide the most accurate estimate of the current Net Footprint in the LICA region, their use highlights data and reporting issues that must be resolved to provide integrated datasets that will help monitor land use changes.

4.1 FINDINGS

The results of application of the protocol and analysis steps for all indicators to the In situ project area are presented in Tables 19 and 20. Study area-specific results (i.e., natural subregions, townships, and watersheds) are provided in Appendix B.

As shown in Figure 20, Land Use Footprint has increased from 12.3% of the project area in 1981 to 18.5% at present (~2001). Although the focus of this project was on the in situ footprint, crop and pasture land was the biggest contributor to cleared area in both time periods (10.7% increasing to 12.8%) for the project area. Most of this footprint is located within the White Area.

Table 19. Terrestrial and aquatic cumulative effect indicators for the In situ project area,73L10 – historical (1981) time period.

In Situ Project Area 73L10	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Mean (km/km²)	Median (km/km²)	Min.	Max.	(ha)	% of Project Area	(ha)	% of Project Area	No.	Median Size (ha)	Min.	Max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.08	0.00	000	2.02	146.23	0.18	—	—	—	—	—	—	25.01	0.07
Truck Trails and Rough	0.14	0.00	0.00	7.74	97.43	0.12	—	—	—	—	—	—	18.27	0.05
Cutlines, Snowmobile/ATV trails	1.03	1.00	0.00	6.87	647.33	0.78	—	—	—	—	—	—	265.13	0.76
Power Lines	0.01	0.00	0.00	1.17	55.55	0.07	—	—	—	—	—	—	10.06	0.03
Pipelines	0.01	0.00	0.00	1.23	17.91	0.02	—	—	—	—	—	—	6.64	0.02
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	6.20	0.01	—	—	—	—	—	—	5.54	0.02
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	39.64	0.05	—	—	—	—	—	—	1.30	0.00
Wellsites	—	—	—	—	204.45	0.25	—	—	—	—	—	—	53.59	0.15
Rural Residential/Cabins	—	—	—	—	64.69	0.08	—	—	—	—	—	—	12.46	0.04
Recreational Facilities	—	—	—	—	32.12	0.04	—	—	—	—	—	—	12.13	0.03
Borrow Pits	—	—	—	—	2.35	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	8,851.04	10.72	—	—	—	—	—	—	545.89	1.57
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.27	1.13	0.00	9.23	10,164.94	12.32	38,466.39	46.59	302	14.53	<0.01	2,607.85	956.02	2.74

Table 20. Terrestrial and aquatic cumulative effect indicators for the In situ project area, 73L10 – current (~2001) time period.

In Situ Project Area 73L10	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Mean (km/km²)	Median (km/km²)	Min.	Max.	(ha)	% of Project Area	(ha)	% of Project Area	No.	Median Size (ha)	Min.	Max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.01	0.00	0.00	1.26	36.30	0.04	—	—	—	—	—	—	5.48	0.02
Secondary Roads	0.27	0.00	0.00	5.35	436.16	0.53	—	—	—	—	—	—	90.85	0.26
Truck Trails and Rough	0.18	0.00	0.00	7.74	118.74	0.14	—	—	—	—	—	—	21.58	0.06
Cutlines, Snowmobile/ATV trails	1.91	1.73	0.00	9.08	1,176.80	1.43	—	—	—	—	—	—	556.22	1.59
Power Lines	0.09	0.00	0.00	1.71	239.99	0.29	—	—	—	—	—	—	52.25	0.15
Pipelines	0.48	0.00	0.00	6.02	596.50	0.72	—	—	—	—	—	—	218.48	0.63
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	6.20	0.01	—	—	—	—	—	—	5.54	0.02
Mines and Quarries	—	—	—	—	46.30	0.06	—	—	—	—	—	—	11.33	0.03
Industrial Facilities	—	—	—	—	640.74	0.78	—	—	—	—	—	—	214.59	0.62
Wellsites	—	—	—	—	849.15	1.03	—	—	—	—	—	—	250.53	0.72
Rural Residential/Cabins	—	—	—	—	71.03	0.09	—	—	—	—	—	—	12.46	0.04
Recreational Facilities	—	—	—	—	38.57	0.05	—	—	—	—	—	—	17.67	0.05
Borrow Pits	—	—	—	—	27.82	0.03	—	—	—	—	—	—	2.58	0.01
Crop/Pasture Land	—	—	—	—	10,549.27	12.78	—	—	—	—	—	—	632.31	1.81
Cutblocks	—	—	—	—	424.89	0.51	—	—	—	—	—	—	66.06	0.19
Current Footprint TOTAL	2.94	2.72	0.00	14.44	15,258.46	18.49	14,581.53	17.66	711	3.91	<0.01	579.17	2,157.93	6.20

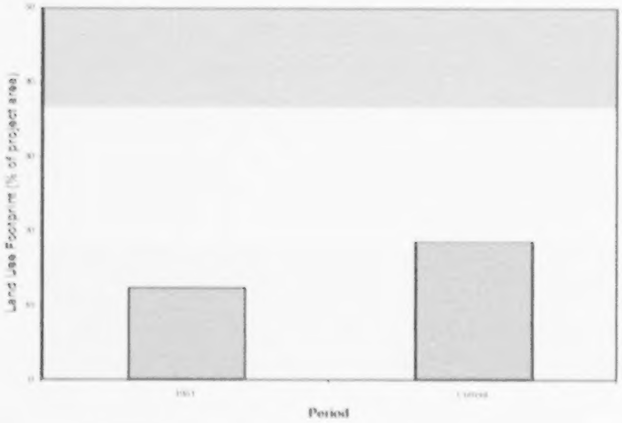

Figure 20. Change in Land Use Footprint since 1981 in comparison to example risk ratings provided in Section 2.2.1. (Low risk = green background; Medium risk = yellow background; High risk = red background).

Since 1981, the footprint of roads, pipelines, power lines, wellsites and industrial facilities increased at the fastest rate (i.e., a minimum 300% increase in cleared area from 1981 to the current time period). This recent industrial footprint growth largely reflects increased in situ development activity in the Green Area (Figure 9).

Average Corridor Density in the project area is currently 2.9 km/km^2, and the density of corridors has more than doubled since 1981 (Figure 21). Seismic lines and trails are the dominant linear feature type, followed by pipelines and secondary roads (Table 20). These results are similar to many areas of Alberta's boreal forest (AEP 1998 and Schneider *et al.* 2003). As mentioned previously, Corridor Density is inversely related to native species diversity and abundance (Section 2.2.2).

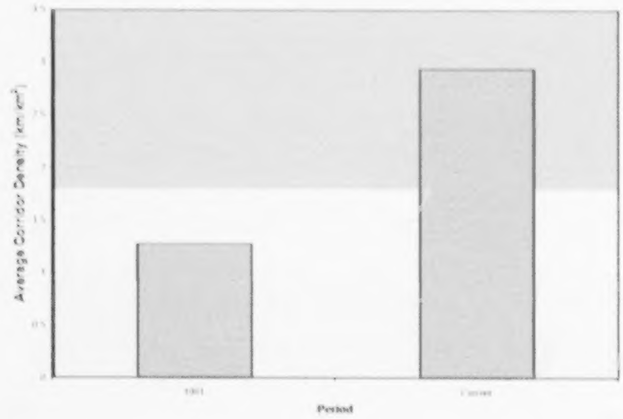

Figure 21. Change in Corridor Density since 1981 in comparison to example risk ratings provided in Section 2.2.2. (Low risk = green background; Medium risk = yellow background; High risk = red background).

The Riparian Footprint more than doubled from 2.7% of riparian habitat in 1981 to 6.2% in ~2001 (Figure 22). Most of this footprint is within wetland complexes in the Jackfish drainage (Figure 14).

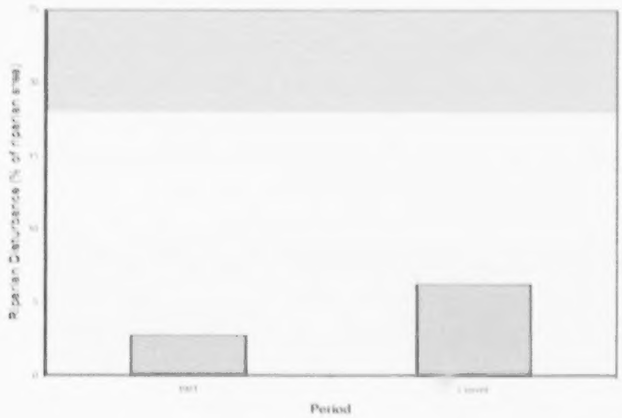

Figure 22. Change in Riparian Footprint since 1981 in comparison to example risk ratings provided in Section 2.2.3. (Low risk = green background; Medium risk = yellow background; High risk = red background).

Core Area analyses demonstrated that currently more than 80% of the project area is within 200 m of land use features (Figure 16). Relatively undisturbed areas outside this indirect footprint represented almost half (47%) of the project area in 1981, but only 17% at present (Figure 23). This landscape fragmentation has substantially increased the risk of adverse cumulative effects on boreal forest ecosystem function.

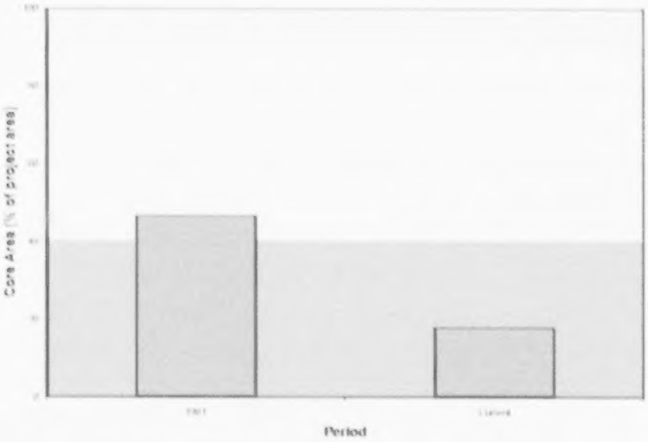

Figure 23. Change in Core Area since 1981 in comparison to example risk ratings provided in Section 2.2.4. (Low risk = green background; Medium risk = yellow background; High risk = red background).

Reclamation status data were not available for most land use features. Analysis for the In situ project area was conducted using well reclamation data; it showed that approximately 0.07% of the In situ project area has been Certified and almost eight times this area (0.52%) was considered Inactive and could be restored. No information on Restored Footprint status was located, and at this time, Net Footprint was assumed to be equal to the Land Use Footprint in the In situ project area.

Include graphics that compare 1981 and present values to ecological thresholds (background shading green, yellow, red to imply risk using same levels provided in Section 2.2)

4.2 ISSUES AND RECOMMENDATIONS

The project team concluded that a regional long-term monitoring program based on the use of existing, readily available data would be most practical and cost-effective at the regional to provincial scale. Because of this, the emphasis in the In situ project was on developing an indicator-based protocol to monitor progress over time, rather than on providing the most accurate 'snapshot' of current conditions in the LICA region. Data limitations presented here demonstrate because of limitations with existing footprint data, accurate footprint snapshots for the LICA region or other areas would require acquisition, digitization, and ground-truthing of high resolution imagery.

While the protocol was applied to one representative area in the LICA region, it can also be applied at larger and smaller scales as well as other areas of the province. The definitions and analysis steps described here were chosen to be broadly applicable. Using a map sheet or township as the basic analysis unit provides a clear and systematic approach to regional or provincial monitoring (see Section 3.1).

As described previously by Matrix (2006), existing permitting and reporting processes deliver limited and inconsistent regional information that is not sufficient for long-term monitoring of combined footprints and associated cumulative effects risk. Cumulative effects evaluations conducted for Environmental Impact Assessments are not incorporated into footprint mapping or cumulative effects mapping at the regional scale. In addition, permitting and reporting data are not currently presented in electronic form, and this discourages integration and evaluation of success.

When developing and applying the In situ footprint protocol, the primary issue for all indicators was the lack of consistent, attributed, geo-referenced land use and reclamation information. In part, this is a result of independent tracking of surface allocations / disturbances and reclamation status by government ministries, agencies, and proponents. The absence of integrated data on reclamation status for all land use features meant that the current Net Footprint could not be accurately calculated.

The following recommendations address data and analysis inadequacies identified during the In situ project as well as suggestions for monitoring protocol implementation by AENV.

Recommendation #1: Implement consistent cross-ministry footprint as-built reporting including geo-referenced data on feature location, type, size, age, and activity status according to prescribed standards.

Accurate, timely, and accessible information is essential for footprint monitoring. The draft Land Use Framework's commitment to an Integrated Information Management system that will monitor the state of the land and the status of land use (ASRD 2008) appears to be an appropriate initiative to implement this and other information management recommendations.

Digital, spatially explicit footprint 'as-built' and reclamation status should be reported by land users (energy, forest aggregate, residential, transportation, and recreational sectors; and municipal and provincial governments) in accordance with pre-defined standards to facilitate updates and integration. Submission of as-built information is critical, because in many situations, actual land use locations differ from those originally proposed in Environmental Impact Assessments or other conceptual applications.

Recommendation #2: Improve and expand the existing base features update system.

The existing ASRD base features update process should be improved and expanded to include all anthropogenic surface disturbances (e.g., well sites, small oil and gas facilities, borrow pits). The apparent lack of a spatially explicit record of well lease footprints present on the land base is a huge data gap in understanding the cumulative effects of hydrocarbon development in the LICA region and elsewhere.

AVI data contains some land use footprint data (e.g., borrow pits), as part of their non-vegetated land classification. Additionally, AVI data is a crown land dataset therefore it would have limited application in the white area. It is recommended that the focus of land use footprint mapping be consolidated within the base features mapping process.

Data currency is an issue. While base features map data are updated on an ongoing basis using aerial photography and satellite imagery, frequent and targeted updating of areas of intensive industrial development is recommended in conjunction with a systematic land use footprint monitoring program.

Recommendation #3: Require reclamation objectives and vegetation status to be included as attributes in all digital land use files and as part of Conservation and Reclamation reporting.

At present, it is not possible to either estimate or monitor the amount of disturbed area that will ultimately be restored to native boreal forest. This creates a critical gap in determining medium- to long-term effects on boreal forest ecosystem function.

The Conservation and Reclamation data provided by Imperial Oil Resources Ltd. provides a good foundation on which to build. Annual or regular updates should be required to monitor changes in footprint indicators and reclamation status. The submission of digital, spatially explicit data identified in Recommendation #1 should also include:

- actual footprint location, size, and status (i.e., Active, Inactive);
- reclamation objectives (i.e., Natural Reclamation to Wetland; Natural Reclamation to Grassland; Natural Reclamation to Forest; Crop and Forage Land; or other agreed-upon objective), andreclamation status relative to objectives (i.e., Restored; Not Yet Restored; Certified) and site-specific soil, vegetation, and landscape monitoring data specified by AENV criteria (1995; 2007).

Conservation and Reclamation reports should also provide summaries that document footprint indicator status for each operator's activities, namely Land Use Footprint, Corridor Density, Core Area, Riparian Area Disturbed, Inactive Footprint, Restored Footprint, and Net Footprint.

Finally, while reclamation reporting requirements are currently restricted to approved in situ projects, this information should be required for all land uses to adequately track footprint status in the LICA region and elsewhere.

Recommendation #4: ***Systematically implement the protocol to document landscape conditions throughout LICA and other parts of the province.***

Footprint monitoring should be expanded in the LICA region and other parts of the province to to fulfill AENV's mandate and provide information for integrated decision making and management. Map sheets or townships provide a systematic framework for monitoring and updating. Where necessary, analyses can also be completed for ecological or administrative areas of interest as shown in the protocol.

Recommendation #5: ***Develop disturbance or reclamation thresholds for the landscape indicators in the LICA region. These management thresholds should be designed to achieve desired regional or provincial social, ecological, and economic outcomes and should be developed with input from regulatory agencies, land users, and the general public.***

The Draft Land-use Framework (ASRD 2008) states that regional plans will identify cumulative effects thresholds to balance environmental objectives and socio-economic values. Development of a regional plan for Northeast Alberta, including the LICA region, is identified as an immediate regional planning priority.

The Northeast Alberta Regional Planning initiative provides an appropriate forum to development disturbance or reclamation thresholds, and AENV should ensure that the landscape indicators presented here are considered during this process.

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APPENDIX A.

Land Use Footprint Type Classification Scheme for ASRD Access Base Feature and AVI Data

Classification of ASRD access base features into land use footprint types.

Access Base Feature Theme				Land Use Footprint Type
ASRD Data Layer Name	Feature Code	Feature type	Description	
Roads Arcs	AQ27700000	FERRY-ROUTE	Ferry crossing	exclude from footprint analysis
Roads Arcs	GA28500000	FORD-WINTER-XING	Ford/winter crossing	truck trails and rough roads
Roads Arcs	DD35100000	INTERCHANGE-RAMP	Interchange ramp	paved roads and highways
Roads Arcs	DA62200010	ROAD-GRAVEL-1L	One lane gravel road	secondary roads
Roads Arcs	DA62200020	ROAD-GRAVEL-2L	Two lane gravel road	secondary roads
Roads Arcs	DA62450000	ROAD-PAVED-DIV	Divided paved road	paved roads and highways
Roads Arcs	DA62500010	ROAD-PAVED-UNDIV-1L	One lane undivided paved road	paved roads and highways
Roads Arcs	DA62500020	ROAD-PAVED-UNDIV-2L	Two lane undivided paved road	paved roads and highways
Roads Arcs	DA62500040	ROAD-PAVED-UNDIV-4L	Four lane undivided paved road	paved roads and highways
Roads Arcs	DA62640000	ROAD-UNCLASSIFIED	Unclassified road	truck trails and rough roads
Roads Arcs	DA62700000	ROAD-UNIMPROVED	Unimproved road	truck trails and rough roads
Roads Arcs	DA62800000	ROAD-WINTER-ROAD	Winter road	truck trails and rough roads
Roads Arcs	DC76500000	TRUCK-TRAIL	Truck trail	truck trails and rough roads
Road Points	AQ27700000	FERRY-ROUTE-EVENT	Ferry route-event	exclude from footprint analysis
Road Points	AR55350000	PORT-OF-ENTRY-EVENT	Port of entry-event	exclude from footprint analysis
Road Points	CZ16280000	MISC-CNTRL-DEV-EVENT	Miscellaneous control device-event	exclude from footprint analysis
Road Points	DD05600000	BRIDGE	Bridge	exclude from footprint analysis
Road Points	DD06000510	BRIDGE-RD-GRVL-1L-EV	Gravel road one lane bridge-event	exclude from footprint analysis
Road Points	DD06000520	BRIDGE-RD-GRVL-2L-EV	Gravel road two lane bridge-event	exclude from footprint analysis
Road Points	DD06000710	BRIDGE-RD-PAV-1L-EV	Paved road one lane bridge-event	exclude from footprint analysis
Road Points	DD06000720	BRIDGE-RD-PAV-2L-EV	Paved road two lane bridge-event	exclude from footprint analysis
Road Points	DD06000740	BRIDGE-RD-PAV-4L-EV	Paved road four lane bridge-event	exclude from footprint analysis
Road Points	DD06000750	BRIDGE-RD-PAV-DIV-EV	Divided paved road bridge-event	exclude from footprint analysis
Road Points	DD06000950	BRIDGE-RD-UNIMP-EV	Unimproved road bridge-event	exclude from footprint analysis
Road Points	DD06150700	BRIDGE-TRL-TRCK-EV	Truck trail bridge-event	exclude from footprint analysis
Road Points	DD35100000	INT-RAMP-EVENT	Interchange ramp-event	exclude from footprint analysis
Road Points	DD49700000	OP-UP-EVENT	Overpass/underpass-event	exclude from footprint analysis
Road Points	DD77500000	TUNNEL-RD-EVENT	Roadway tunnel event	exclude from footprint analysis

Access Base Feature Theme				
ASRD Data Layer Name	Feature Code	Feature type	Description	Land Use Footprint Type
Road Points	GA28500000	FORD WINTR XING EV	Ford/winter crossing event	exclude from footprint analysis
Cutline Trail Arcs	DC76100000	CUTLINE-TRAIL	Cutline/trail	cutlines, snowmobile & ATV trails
Cutline Trail Arcs	DC76130000	TRAIL-ATV	ATV trail	cutlines, snowmobile & ATV trails
Cutline Trail Arcs	DC76130400	TRAIL-ATV-INDEFINITE	ATV indefinite trail	cutlines, snowmobile & ATV trails
Cutline Trail Arcs	DC76610000	CUTLINE-TRAIL-WITHIN-CLEARING	Cutline/trail within a clearing	cutlines, snowmobile & ATV trails
Railway Arcs	DC57060000	RLWY-FORMER	Former rail line	truck trails and rough roads
Railway Arcs	DE56950000	RLWY-ABANDONED	Abandoned rail line	truck trails and rough roads
Railway Arcs	DE57000000	RLWY-DBL-TRACK	Double track rail line	railways
Railway Arcs	DE57100000	RLWY-MLT-TRACK	Multiple track rail line	railways
Railway Arcs	DE57250000	RLWY-SGL-TRACK	Single track rail line	railways
Railway Arcs	DF57300000	RLWY-SPUR	Rail line spur	railways
Railway Points	AR54500000	RLWY-PT-EVENT	Railway point event	exclude from footprint analysis
Railway Points	DD05950600	BRIDGE-RLWY-SPUR-EV	Railway spur bridge event	exclude from footprint analysis
Railway Points	DD05950800	BRIDGE-RLWY-EVENT	Railway trestle bridge event	exclude from footprint analysis
Railway Points	DD774450000	TUNNEL-RLWY-EVENT	Railway tunnel event	exclude from footprint analysis
Pipeline Arcs	EA52550000	PIPELINE	Pipeline	pipelines
Powerline Arcs	EA40650300	TRANS-LINE	Electrical transmission line with voltage greater than 69 kV	power lines
Facility Points	AQ32550000	HELIPORT-EVENT	Heliport event	industrial facility
Facility Points	AQ32550000	HELIPORT-EVENT-AB	Abandoned Heliport event	other clearings
Facility Points	BF07120000	CABIN-LOOKOUT	Lookout cabin	rural residential / cabins
Facility Points	BF32305000	HQ-PROVINCIAL	Provincial Headquarters	industrial facility
Facility Points	BF49160000	OFFICE-WILDFIRE-MANAGEMENT	Wildfire Management Office	industrial facility
Facility Points	BF74600500	TOWER-LOOKOUT	Lookout tower	rural residential / cabins
Facility Points	CC74750000	TOWER-MAJOR	Major tower/mast (communications	rural residential / cabins
Access Polygon	AG34950000	OTH-IND-SITE	Other industrial site	industrial facility
Access Polygon	AG34950100	COMMERCIAL-SITE	Commercial site	industrial facility
Access Polygon	AG45350000	OPEN-PIT-MINE	Open pit mining operation	mines and quarries
Access Polygon	AG53100000	GRVL-SAND-PIT	Gravel/sand pit	mines and quarries
Access Polygon	AP52050000	TAILING-PILE	Tailing pile/pond/dump	mines and quarries

Access Base Feature Theme				Land Use Footprint Type
ASRD Data Layer Name	**Feature Code**	**Feature type**	**Description**	
Access Polygon	AQ63700000	AIRF-RUNWAY-ACTIVE	Airfield runway	airstrip
Access Polygon	AQ63700100	AIRF-RUNWAY-ABAND	Abandoned airfield runway	truck trails and rough roads
Access Polygon	AQ63750000	AIRP-RUNWAY-ACTIVE	Airport runway	airstrip
Access Polygon	AQ63750100	AIRP-RUNWAY-ABAND	Abandoned airport runway	truck trails and rough roads
Access Polygon	AQ63801000	AIRS-RUNWAY-ACTIVE	Airstrip runway	airstrip
Access Polygon	AQ63801100	AIRS-RUNWAY-ABAND	Abandoned airstrip runway	truck trails and rough roads
Access Polygon	BG43000000	MAJ-MILL	Major mill site	industrial facility
Access Polygon	BG53580000	OIL-GAS-PLANT	Oil/gas plant	industrial facility
Access Polygon	BG70580000	PWR-GEN-STA	Power generating station	industrial facility

Classification of AVI data into land use footprint types.

General AVI cover type classification	**Specific classification** – *with comments*	**Variable Name (Code)**	**Land Use Footprint Type**
Anthropogenic non-vegetated industrial development	gravel pits including borrow pits	ANTH_NON (AIG)	Borrow pits
Anthropogenic non-vegetated settlement areas	cities, towns, villages, hamlets – *covered by ASRD base features data*	ANTH_NON (ASC)	Communities
Anthropogenic vegetated agriculture	annual crops; perennial crops; rough pasture	ANTH_VEG (CA, CP, CPR)	Crop and pasture land
Forest land stand condition modifier	clearcut/partial cut	MOD1 (CC)	Cutblocks
Forest land stand condition extent code	severe (76-94% of area affected); entire (100% of area affected)	MOD1EXT (4,5)	
Forest land treatment modifier	seedbed prepared - *29 of 75 clearcut polygons were listed as having a seedbed prepared, but few dates were given for year of treatment. These polygons were included as cutblocks.*	MOD2 (SC)	
Anthropogenic non-vegetated industrial development	industrial (plant sites), sewage lagoons	ANTH_NON (AII)	Industrial Facilities
Anthropogenic non-vegetated industrial development	peat extractions; surface mines – *none show to exist in the In situ project area*	ANTH_NON (AIE, AIM)	Mines and quarries
Anthropogenic non-vegetated industrial development	farmsteads (related to agriculture)	ANTH_NON (AIF)	Rural residential
Anthropogenic non-vegetated settlement areas	Ribbon development, rural recreation (e.g., rural stores and isolated housing sub-divisions, cottages, rural residential, acreage owners, (agriculture is not the primary source of income) – *covered by ASRD base features data*	ANTH_NON (ASR)	

NOTE: Shaded areas represent land use footprint classes that exist in the AVI data, but were not used for the In situ project.

APPENDIX B.

Footprint Indicator Results for all Study Areas within the 73L10 Project Area

Terrestrial and Aquatic Cumulative Effect Indicators for the Jackfish Watershed (WS) – Current (~2001) time period

Jackfish Watershed	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Average (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of WS	(ha)	% of WS	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.01	0.00	0.00	1.26	36.30	0.06	—	—	—	—	—	—	5.48	0.03
Secondary Roads	0.29	0.00	0.00	5.35	309.55	0.54	—	—	—	—	—	—	60.15	0.30
Truck Trails and Rough	0.19	0.00	0.00	3.77	102.43	0.18	—	—	—	—	—	—	16.93	0.08
Cutlines, Snowmobile/ATV trails	1.89	1.69	0.00	9.08	780.76	1.36	—	—	—	—	—	—	331.48	1.63
Power Lines	0.10	0.00	0.00	2.47	119.19	0.21	—	—	—	—	—	—	27.00	0.13
Pipelines	0.56	0.00	0.00	12.79	406.53	0.71	—	—	—	—	—	—	153.09	0.75
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	6.22	0.01	—	—	—	—	—	—	5.54	0.03
Mines and Quarries	—	—	—	—	46.30	0.08	—	—	—	—	—	—	11.33	0.06
Industrial Facilities	—	—	—	—	424.14	0.74	—	—	—	—	—	—	142.02	0.70
Wellsites	—	—	—	—	589.22	1.02	—	—	—	—	—	—	163.32	0.80
Rural Residential/Cabins	—	—	—	—	69.78	0.12	—	—	—	—	—	—	11.52	0.06
Recreational Facilities	—	—	—	—	2.73	0.00	—	—	—	—	—	—	2.07	0.01
Borrow Pits	—	—	—	—	19.58	0.03	—	—	—	—	—	—	1.86	0.01
Crop/Pasture Land	—	—	—	—	9596.93	16.69	—	—	—	—	—	—	600.74	2.95
Cutblocks	—	—	—	—	186.85	0.32	—	—	—	—	—	—	28.10	0.14
Current Footprint TOTAL	3.04	2.80	0.00	14.44	12,696.51	22.07	9,326.02	16.22	438	4.11	<0.01	892.91	1,560.63	7.68

Terrestrial and aquatic cumulative effect indicators for the Sand Watershed (WS) – current (~2001) time period.

Sand Watershed	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Average (km/km²)	Median (km/km²)	min.	max.	(ha)	% of WS	(ha)	% of WS	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.19	0.00	0.00	2.60	126.61	0.39	—	—	—	—	—	—	30.70	0.21
Truck Trails and Rough	0.09	0.00	0.00	4.17	16.31	0.05	—	—	—	—	—	—	4.65	0.03
Cutlines, Snowmobile/ATV trails	1.61	1.40	0.00	10.38	396.28	1.23	—	—	—	—	—	—	224.73	1.55
Power Lines	0.09	0.00	0.00	2.00	120.79	0.37	—	—	—	—	—	—	25.25	0.17
Pipelines	0.38	0.00	0.00	6.75	189.97	0.59	—	—	—	—	—	—	65.39	0.45
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	220.13	0.68	—	—	—	—	—	—	72.57	0.50
Wellsites	—	—	—	—	263.98	0.82	—	—	—	—	—	—	87.21	0.60
Rural Residential/Cabins	—	—	—	—	1.24	0.00	—	—	—	—	—	—	0.94	0.01
Recreational Facilities	—	—	—	—	35.86	0.11	—	—	—	—	—	—	15.60	0.11
Borrow Pits	—	—	—	—	8.24	0.03	—	—	—	—	—	—	0.72	0.00
Crop/Pasture Land	—	—	—	—	954.77	2.96	—	—	—	—	—	—	31.56	0.22
Cutblocks	—	—	—	—	238.03	0.74	—	—	—	—	—	—	37.96	0.26
Current Footprint TOTAL	2.36	1.99	0.00	17.13	2,572.21	7.97	11,824.55	36.61	237	3.51	<0.01	4,568.40	597.28	4.11

Terrestrial and aquatic cumulative effect Indicators for the Central Mixedwood Natural Subregion (NSR) – current (~2001) time period.

Central Mixedwood Natural Subregion	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Average (km/km²)	Median (km/km²)	min.	max.	(ha)	% of NSR	(ha)	% of NSR	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	1.38	3.51	0.01	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.27	0.00	0.00	5.35	368.58	0.53	—	—	—	—	—	—	73.95	0.25
Truck Trails and Rough	0.13	0.00	0.00	3.77	75.46	0.11	—	—	—	—	—	—	12.64	0.04
Cutlines, Snowmobile/ATV trails	1.87	1.72	0.00	9.73	990.74	1.41	—	—	—	—	—	—	465.59	1.55
Power Lines	0.10	0.00	0.00	1.78	220.91	0.31	—	—	—	—	—	—	43.31	0.14
Pipelines	0.48	0.00	0.00	6.02	541.70	0.77	—	—	—	—	—	—	194.20	0.65
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	46.30	0.07	—	—	—	—	—	—	11.33	0.04
Industrial Facilities	—	—	—	—	573.67	0.82	—	—	—	—	—	—	189.56	0.63
Wellsites	—	—	—	—	762.63	1.09	—	—	—	—	—	—	231.19	0.77
Rural Residential/Cabins	—	—	—	—	18.04	0.03	—	—	—	—	—	—	1.22	0.00
Recreational Facilities	—	—	—	—	35.86	0.05	—	—	—	—	—	—	15.60	0.05
Borrow Pits	—	—	—	—	26.28	0.04	—	—	—	—	—	—	2.58	0.01
Crop/Pasture Land	—	—	—	—	7,164.57	10.21	—	—	—	—	—	—	275.87	0.92
Cutblocks	—	—	—	—	424.89	0.61	—	—	—	—	—	—	66.06	0.22
Current Footprint TOTAL	2.86	2.60	0.00	14.44	11,253.14	16.06	13,635.35	19.44	614	4.21	<0.01	579.17	1,583.10	5.27

Terrestrial and aquatic cumulative effect indicators for the Dry Mixedwood Natural Subregion – current (~2001) time period.

Dry Mixedwood Natural Subregion	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Average (km/km²)	Median (km/km²)	min.	max.	(ha)	% of NSR	(ha)	% of NSR	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.05	0.00	0.00	1.14	32.79	0.26	—	—	—	—	—	—	5.48	0.11
Secondary Roads	0.28	0.00	0.00	8.89	67.58	0.54	—	—	—	—	—	—	16.91	0.35
Truck Trails and Rough	0.41	0.00	0.00	7.74	43.29	0.35	—	—	—	—	—	—	8.94	0.18
Cutlines, Snowmobile/ATV trails	2.25	1.73	0.00	9.67	186.06	1.50	—	—	—	—	—	—	90.63	1.85
Power Lines	0.08	0.00	0.00	1.89	19.08	0.15	—	—	—	—	—	—	8.94	0.18
Pipelines	0.43	0.00	0.00	2.71	54.80	0.44	—	—	—	—	—	—	24.28	0.50
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	6.20	0.05	—	—	—	—	—	—	5.54	0.11
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	67.08	0.54	—	—	—	—	—	—	25.03	0.51
Wellsites	—	—	—	—	86.51	0.70	—	—	—	—	—	—	19.35	0.40
Rural Residential/Cabins	—	—	—	—	52.99	0.43	—	—	—	—	—	—	11.23	0.23
Recreational Facilities	—	—	—	—	2.72	0.02	—	—	—	—	—	—	2.07	0.04
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	3,384.70	27.29	—	—	—	—	—	—	356.44	7.29
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Current Footprint TOTAL	3.48	3.1	0	11.24	4,003.80	32.27	946.18	7.63	108	1.45	<0.01	162.51	574.84	11.75

Terrestrial and aquatic cumulative effect indicators for Township 64, Range 4, W4M – current (~2001) time period

Township 64, Range 4, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Average (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	5.48	0.11
Secondary Roads	0.27	0.00	0.00	2.73	36.50	0.64	—	—	—	—	—	—	3.26	0.21
Truck Trails and Rough	0.46	0.00	0.00	9.54	14.75	0.26	—	—	—	—	—	—	2.19	0.14
Cutlines, Snowmobile/ATV trails	2.13	2.07	0.00	6.87	93.23	1.63	—	—	—	—	—	—	20.67	1.36
Power Lines	0.12	0.00	0.00	1.17	1.48	0.03	—	—	—	—	—	—	0.05	0.00
Pipelines	0.48	0.00	0.00	2.40	36.23	0.63	—	—	—	—	—	—	3.25	0.21
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	6.20	0.11	—	—	—	—	—	—	5.54	0.36
Mines and Quarries	—	—	—	—	19.45	0.34	—	—	—	—	—	—	2.58	0.17
Industrial Facilities	—	—	—	—	27.13	0.48	—	—	—	—	—	—	6.46	0.42
Wellsites	—	—	—	—	85.06	1.49	—	—	—	—	—	—	14.02	0.92
Rural Residential/Cabins	—	—	—	—	20.84	0.37	—	—	—	—	—	—	10.32	0.68
Recreational Facilities	—	—	—	—	2.72	0.05	—	—	—	—	—	—	2.07	0.14
Borrow Pits	—	—	—	—	0.71	0.01	—	—	—	—	—	—	0.19	0.01
Crop/Pasture Land	—	—	—	—	137.73	2.41	—	—	—	—	—	—	14.06	0.92
Cutblocks	—	—	—	—	30.37	0.53	—	—	—	—	—	—	3.37	0.22
Current Footprint TOTAL	3.46	3.27	0.00	11.05	512.40	8.98	1,137.77	19.93	51	4.17	<0.01	163.77	93.51	5.87

Terrestrial and aquatic cumulative effect indicators for Township 64, Range 5, W4M – current (~2001) time period.

Township 64, Range 5, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Average (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.08	0.00	0.00	1.68	13.03	0.14	—	—	—	—	—	—	2.81	0.09
Truck Trails and Rough	0.44	0.00	0.00	3.77	42.35	0.46	—	—	—	—	—	—	8.02	0.26
Cutlines, Snowmobile/ATV trails	2.84	2.65	0.00	7.01	192.95	2.09	—	—	—	—	—	—	65.37	2.09
Power Lines	0.15	0.00	0.00	1.15	24.25	0.26	—	—	—	—	—	—	10.26	0.33
Pipelines	0.29	0.00	0.00	1.93	29.87	0.32	—	—	—	—	—	—	12.16	0.39
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	11.38	0.12	—	—	—	—	—	—	2.81	0.09
Industrial Facilities	—	—	—	—	0.26	0.00	—	—	—	—	—	—	0.19	0.01
Wellsites	—	—	—	—	29.04	0.31	—	—	—	—	—	—	8.84	0.28
Rural Residential/Cabins	—	—	—	—	9.65	0.10	—	—	—	—	—	—	0.15	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	8.44	0.09	—	—	—	—	—	—	0.48	0.02
Crop/Pasture Land	—	—	—	—	1,220.12	13.23	—	—	—	—	—	—	124.67	3.98
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Current Footprint TOTAL	3.81	3.78	0.25	8.86	1,581.34	17.12	906.91	9.84	93	2.45	<0.01	162.51	235.76	7.54

Terrestrial and aquatic cumulative effect indicators for Township 64, Range 6, W4M – current (~2001) time period.

Township 64, Range 6, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Average (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.29	0.00	0.00	2.14	58.23	0.66	—	—	—	—	—	—	12.12	0.47
Truck Trails and Rough	0.36	0.00	0.00	5.94	27.75	0.31	—	—	—	—	—	—	3.38	0.13
Cutlines, Snowmobile/ATV trails	2.01	1.68	0.00	9.08	97.44	1.10	—	—	—	—	—	—	50.01	1.92
Power Lines	0.13	0.00	0.00	1.84	6.28	0.07	—	—	—	—	—	—	2.64	0.10
Pipelines	0.44	0.00	0.00	2.71	32.62	0.37	—	—	—	—	—	—	15.57	0.60
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	50.58	0.57	—	—	—	—	—	—	17.58	0.68
Wellsites	—	—	—	—	71.35	0.81	—	—	—	—	—	—	13.27	0.51
Rural Residential/Cabins	—	—	—	—	16.75	0.19	—	—	—	—	—	—	0.28	0.01
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	3.80	0.04	—	—	—	—	—	—	0.04	0.00
Crop/Pasture Land	—	—	—	—	4,050.77	45.91	—	—	—	—	—	—	195.23	7.50
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Current Footprint TOTAL	3.23	2.99	0.00	11.24	4,415.57	50.03	227.83	2.58	53	0.67	<0.01	34.11	310.12	11.92

Terrestrial and aquatic cumulative effect indicators for Township 64, Range 7, W4M – current (~2001) time period.

Township 64, Range 7, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Average (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.12	0.00	0.00	1.26	36.00	0.66	—	—	—	—	—	—	5.48	0.36
Secondary Roads	0.38	0.00	0.00	2.05	43.41	0.80	—	—	—	—	—	—	7.80	0.51
Truck Trails and Rough	0.14	0.00	0.00	1.17	7.44	0.14	—	—	—	—	—	—	0.72	0.05
Cutlines, Snowmobile/ATV trails	1.87	1.23	0.00	7.29	59.44	1.09	—	—	—	—	—	—	21.91	1.43
Power Lines	0.13	0.00	0.00	1.30	2.41	0.04	—	—	—	—	—	—	0.92	0.06
Pipelines	0.38	0.00	0.00	2.78	17.99	0.33	—	—	—	—	—	—	6.32	0.41
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	25.75	0.47	—	—	—	—	—	—	7.25	0.47
Wellsites	—	—	—	—	28.71	0.53	—	—	—	—	—	—	3.22	0.21
Rural Residential/Cabins	—	—	—	—	21.03	0.39	—	—	—	—	—	—	0.77	0.05
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	2,302.41	42.29	—	—	—	—	—	—	196.89	12.87
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Current Footprint TOTAL	3.02	2.94	0.00	7.38	2,544.59	46.74	190.86	3.51	28	1.31	<0.01	63.74	251.28	16.42

Terrestrial and aquatic cumulative effect indicators for Township 65, Range 4, W4M – current (~2001) time period.

Township 65, Range 4, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Average (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.99	0.48	0.00	6.00	115.69	1.77	—	—	—	—	—	—	24.61	0.83
Truck Trails and Rough	0.22	0.00	0.00	2.43	8.10	0.12	—	—	—	—	—	—	1.82	0.06
Cutlines, Snowmobile/ATV trails	1.61	1.51	0.00	6.72	83.72	1.28	—	—	—	—	—	—	43.63	1.47
Power Lines	0.15	0.00	0.00	1.33	50.54	0.77	—	—	—	—	—	—	8.62	0.29
Pipelines	1.29	1.04	0.00	5.90	116.06	1.77	—	—	—	—	—	—	42.79	1.44
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	245.74	3.76	—	—	—	—	—	—	88.15	2.97
Wellsites	—	—	—	—	236.11	3.61	—	—	—	—	—	—	76.22	2.56
Rural Residential/Cabins	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutblocks	—	—	—	—	27.70	0.42	—	—	—	—	—	—	1.60	0.05
Current Footprint TOTAL	4.25	3.36	0.00	14.44	883.66	13.50	910.98	13.92	57	6.20	<0.01	139.55	287.44	9.67

Terrestrial and aquatic cumulative effect indicators for Township 65, Range 5, W4M – current (~2001) time period.

Township 65, Range 5, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Average (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.08	0.00	0.00	1.26	3.64	0.08	—	—	—	—	—	—	3.64	0.08
Truck Trails and Rough	0.03	0.00	0.00	1.90	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutlines, Snowmobile/ATV trails	2.12	1.97	0.00	6.23	158.83	1.80	—	—	—	—	—	—	94.64	1.96
Power Lines	0.05	0.00	0.00	1.21	23.05	0.26	—	—	—	—	—	—	1.26	0.03
Pipelines	0.28	0.00	0.00	2.24	51.08	0.58	—	—	—	—	—	—	26.30	0.54
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	10.05	0.11	—	—	—	—	—	—	6.09	0.13
Wellsites	—	—	—	—	63.14	0.71	—	—	—	—	—	—	29.74	0.61
Rural Residential/Cabins	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	157.73	1.78	—	—	—	—	—	—	3.06	0.06
Cutblocks	—	—	—	—	30.33	0.34	—	—	—	—	—	—	7.88	0.16
Current Footprint TOTAL	2.56	2.29	0.00	8.46	497.85	5.66	1,955.43	22.11	96	3.66	<0.01	228.72	172.61	3.57

Terrestrial and aquatic cumulative effect indicators for Township 65, Range 6, W4M – current (~2001) time period.

Township 65, Range 6, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Average (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.09	0.00	0.00	1.67	15.53	0.17	—	—	—	—	—	—	3.73	0.09
Truck Trails and Rough	0.05	0.00	0.00	2.13	3.73	0.04	—	—	—	—	—	—	0.05	0.00
Cutlines, Snowmobile/ATV trails	1.46	1.31	0.00	5.85	89.58	0.98	—	—	—	—	—	—	49.58	1.19
Power Lines	0.07	0.00	0.00	1.24	27.27	0.30	—	—	—	—	—	—	2.62	0.06
Pipelines	0.25	0.00	0.00	1.87	35.57	0.39	—	—	—	—	—	—	5.68	0.14
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	45.21	0.50	—	—	—	—	—	—	15.11	0.36
Wellsites	—	—	—	—	37.23	0.41	—	—	—	—	—	—	7.48	0.18
Rural Residential/Cabins	—	—	—	—	0.94	0.01	—	—	—	—	—	—	0.94	0.02
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	2,189.29	24.01	—	—	—	—	—	—	92.23	2.21
Cutblocks	—	—	—	—	40.35	0.44	—	—	—	—	—	—	12.11	0.29
Current Footprint TOTAL	1.92	1.65	0.00	6.37	2,484.70	27.25	1,951.73	21.41	59	6.32	<0.01	417.59	189.53	4.54

Terrestrial and aquatic cumulative effect indicators for Township 65, Range 7, W4M – current (~2001) time period.

Township 65, Range 7, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Average (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Secondary Roads	0.10	0.00	0.00	1.19	13.20	0.25	–	–	–	–	–	–	0.38	0.02
Truck Trails and Rough	0.02	0.00	0.00	0.75	1.10	0.02	–	–	–	–	–	–	0.25	0.01
Cutlines, Snowmobile/ATV trails	1.81	1.84	0.00	8.54	74.94	1.42	–	–	–	–	–	–	28.16	1.45
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Pipelines	0.44	0.00	0.00	2.25	35.57	0.68	–	–	–	–	–	–	9.96	0.51
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Communities	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Mines and Quarries	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Industrial Facilities	–	–	–	–	18.48	0.35	–	–	–	–	–	–	4.53	0.23
Wellsites	–	–	–	–	14.61	0.28	–	–	–	–	–	–	3.40	0.17
Rural Residential/Cabins	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Recreational Facilities	–	–	–	–	35.86	0.68	–	–	–	–	–	–	15.60	0.80
Borrow Pits	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Crop/Pasture Land	–	–	–	–	488.37	9.27	–	–	–	–	–	–	6.18	0.32
Cutblocks	–	–	–	–	15.33	0.29	–	–	–	–	–	–	3.97	0.20
Current Footprint TOTAL	2.37	2.36	0.00	8.54	697.46	13.24	1,115.97	21.19	60	5.72	<0.01	246.39	72.43	3.71

Terrestrial and aquatic cumulative effect indicators for Township 66, Range 4, W4M – current (~2001) time period.

Township 66, Range 4, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Average (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Secondary Roads	0.30	0.00	0.00	3.26	28.25	0.49	–	–	–	–	–	–	6.15	0.21
Truck Trails and Rough	0.02	0.00	0.00	0.56	1.02	0.02	–	–	–	–	–	–	0.72	0.02
Cutlines, Snowmobile/ATV trails	1.89	1.92	0.00	5.11	84.69	1.48	–	–	–	–	–	–	42.63	1.46
Power Lines	0.06	0.00	0.00	1.20	17.60	0.31	–	–	–	–	–	–	1.99	0.07
Pipelines	0.90	0.37	0.00	6.21	83.26	1.45	–	–	–	–	–	–	37.70	1.29
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Communities	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Mines and Quarries	–	–	–	–	15.47	0.27	–	–	–	–	–	–	5.94	0.20
Industrial Facilities	–	–	–	–	29.39	0.51	–	–	–	–	–	–	6.82	0.23
Wellsites	–	–	–	–	77.46	1.36	–	–	–	–	–	–	28.42	0.97
Rural Residential/Cabins	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Recreational Facilities	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Borrow Pits	–	–	–	–	6.16	0.11	–	–	–	–	–	–	1.16	0.04
Crop/Pasture Land	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Cutblocks	–	–	–	–	94.65	1.65	–	–	–	–	–	–	13.11	0.45
Current Footprint TOTAL	3.17	2.90	0.00	12.00	437.95	7.64	1,060.43	18.48	71	6.66	0.02	118.14	144.64	4.94

Terrestrial and aquatic cumulative effect indicators for Township 66, Range 5, W4M – current (~2001) time period.

Township 66, Range 5, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Average (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.42	0.00	0.00	2.60	72.28	0.91	—	—	—	—	—	—	19.72	0.55
Truck Trails and Rough	0.18	0.00	0.00	3.13	9.54	0.12	—	—	—	—	—	—	4.34	0.12
Cutlines, Snowmobile/ATV trails	1.91	1.71	0.00	6.78	112.16	1.42	—	—	—	—	—	—	58.39	1.62
Power Lines	0.21	0.00	0.00	1.61	86.94	1.10	—	—	—	—	—	—	23.89	0.66
Pipelines	1.02	0.78	0.00	14.55	117.65	1.48	—	—	—	—	—	—	41.36	1.14
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	183.51	2.32	—	—	—	—	—	—	58.63	1.62
Wellsites	—	—	—	—	167.39	2.11	—	—	—	—	—	—	53.11	1.47
Rural Residential/Cabins	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	8.24	0.10	—	—	—	—	—	—	0.72	0.02
Crop/Pasture Land	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutblocks	—	—	—	—	67.45	0.85	—	—	—	—	—	—	8.50	0.24
Current Footprint TOTAL	3.75	3.37	0.00	15.61	825.16	10.41	1,602.01	20.22	81	3.08	<0.01	297.12	268.66	7.44

Terrestrial and aquatic cumulative effect indicators for Township 66, Range 6, W4M – current (~2001) time period.

Township 66, Range 6, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Average (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Secondary Roads	0.16	0.00	0.00	2.49	24.98	0.34	–	–	–	–	–	–	6.61	0.15
Truck Trails and Rough	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Cutlines, Snowmobile/ATV trails	1.76	1.68	0.00	5.58	107.95	1.47	–	–	–	–	–	–	72.78	1.62
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Pipelines	0.28	0.00	0.00	3.52	39.89	0.54	–	–	–	–	–	–	17.40	0.39
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Communities	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Mines and Quarries	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Industrial Facilities	–	–	–	–	4.65	0.06	–	–	–	–	–	–	3.77	0.08
Wellsites	–	–	–	–	37.21	0.51	–	–	–	–	–	–	12.81	0.28
Rural Residential/Cabins	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Recreational Facilities	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Borrow Pits	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Crop/Pasture Land	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Cutblocks	–	–	–	–	118.72	1.62	–	–	–	–	–	–	15.52	0.35
Current Footprint TOTAL	2.21	2.03	0.00	11.37	333.40	4.54	2220.19	30.24	71	6.05	<0.01	301.55	128.89	2.87

Terrestrial and aquatic cumulative effect indicators for Township 66, Range 7, W4M – current (~2001) time period.

Township 66, Range 7, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Average (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Truck Trails and Rough	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutlines, Snowmobile/ATV trails	0.62	0.00	0.00	3.70	19.16	0.79	—	—	—	—	—	—	8.27	0.75
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Rural Residential/Cabins	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Current Footprint TOTAL	0.62	0.00	0.00	3.70	19.16	0.79	1,292.51	53.59	20	12.44	<0.01	579.17	8.27	0.75

Certified and inactive footprint indicators for the In situ project area (73L10) and for each subregion – current (~2001) time period.

Study Area	**Certified Footprint (ha)**	**% of Study Area**	**Inactive Footprint (ha)**	**% of Study Area**
Project Area (73L10)	54.06	0.07	425.39	0.52
Jackfish Watershed	51.35	0.09	271.64	0.47
Sand Watershed	2.71	0.01	153.75	0.48
Central Mixedwood	25.30	0.04	395.98	0.56
Dry Mixedwood	28.76	0.23	29.41	0.24
Township 64, Range 4	2.11	0.04	56.20	0.98
Township 64, Range 5	14.52	0.16	6.05	0.07
Township 64, Range 6	18.13	0.21	28.26	0.32
Township 64, Range 7	13.31	0.24	6.00	0.11
Township 65, Range 4	0.00	0.00	82.90	1.27
Township 65, Range 5	2.42	0.03	50.67	0.57
Township 65, Range 6	0.00	0.00	23.49	0.26
Township 65, Range 7	0.00	0.00	4.84	0.09
Township 66, Range 4	1.16	0.02	55.11	0.96
Township 66, Range 5	1.21	0.02	88.13	1.11
Township 66, Range 6	1.21	0.02	22.53	0.31
Township 66, Range 7	0.00	0.00	1.21	0.05

Terrestrial and aquatic cumulative effect indicators for the Jackfish Watershed (WS) – historical (1981) time period

Jackfish Watershed	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Mean (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of WS	(ha)	% of WS	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.08	0.00	0.00	2.61	94.31	0.16	—	—	—	—	—	—	16.76	0.08
Truck Trails and Rough	0.16	0.00	0.00	2.68	89.39	0.16	—	—	—	—	—	—	17.41	0.09
Cutlines, Snowmobile/ATV trails	1.00	0.95	0.00	6.61	418.15	0.73	—	—	—	—	—	—	152.51	0.75
Power Lines	0.02	0.00	0.00	1.13	55.55	0.10	—	—	—	—	—	—	10.06	0.05
Pipelines	0.02	0.00	0.00	1.19	17.91	0.03	—	—	—	—	—	—	6.64	0.03
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	6.22	0.01	—	—	—	—	—	—	5.54	0.03
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.26	0.00	—	—	—	—	—	—	0.19	0.00
Wellsites	—	—	—	—	137.62	0.24	—	—	—	—	—	—	36.12	0.18
Rural Residential/Cabins	—	—	—	—	63.47	0.11	—	—	—	—	—	—	11.52	0.06
Recreational Facilities	—	—	—	—	2.73	0.00	—	—	—	—	—	—	2.07	0.01
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	8,475.03	14.74	—	—	—	—	—	—	534.10	2.62
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.28	1.13	0.00	6.61	9,360.64	16.28	24,353.22	42.35	193	16.16	<0.01	2,251.84	792.92	3.90

Terrestrial and aquatic cumulative effect indicators for the Sand Watershed (WS) – historical (1981) time period

Sand Watershed	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	**Mean (km/km²)**	**Median (km/km²)**	min.	max.	(ha)	% of WS	(ha)	% of WS	No.	**Median** Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.08	0.00	0.00	1.82	51.92	0.16	—	—	—	—	—	—	8.24	0.06
Truck Trails and Rough	0.05	0.00	0.00	4.17	8.04	0.02	—	—	—	—	—	—	0.87	0.01
Cutlines, Snowmobile/ATV trails	0.88	0.51	0.00	10.38	229.20	0.71	—	—	—	—	—	—	112.62	0.78
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	39.38	0.12	—	—	—	—	—	—	1.11	0.01
Wellsites	—	—	—	—	66.83	0.21	—	—	—	—	—	—	17.47	0.12
Rural Residential/Cabins	—	—	—	—	1.21	0.00	—	—	—	—	—	—	0.94	0.01
Recreational Facilities	—	—	—	—	29.40	0.09	—	—	—	—	—	—	10.06	0.07
Borrow Pits	—	—	—	—	2.35	0.01	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	378.45	1.17	—	—	—	—	—	—	11.80	0.08
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.01	0.80	0.00	10.38	806.78	2.49	20,924.31	64.78	88	13.78	<0.01	5,866.69	163.11	1.14

Terrestrial and aquatic cumulative effect indicators for the Central Mixedwood Natural Subregion (NSR) – historical (1981) time period

Central Mixedwood Natural Subregion	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Mean (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of NSR	(ha)	% of NSR	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.05	0.00	0.00	2.27	75.43	0.11	—	—	—	—	—	—	11.13	0.04
Truck Trails and Rough	0.10	0.00	0.00	2.48	61.66	0.09	—	—	—	—	—	—	9.44	0.03
Cutlines, Snowmobile/ATV trails	1.04	1.00	0.00	9.58	558.91	0.80	—	—	—	—	—	—	231.05	0.77
Power Lines	0.01	0.00	0.00	1.17	32.09	0.05	—	—	—	—	—	—	1.86	0.01
Pipelines	0.01	0.00	0.00	1.23	9.09	0.01	—	—	—	—	—	—	0.48	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	39.38	0.06	—	—	—	—	—	—	1.11	0.00
Wellsites	—	—	—	—	178.00	0.25	—	—	—	—	—	—	47.27	0.16
Rural Residential/Cabins	—	—	—	—	12.79	0.02	—	—	—	—	—	—	1.22	0.00
Recreational Facilities	—	—	—	—	29.40	0.04	—	—	—	—	—	—	10.06	0.03
Borrow Pits	—	—	—	—	2.35	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	5,701.47	8.13	—	—	—	—	—	—	224.30	0.75
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.20	1.03	0.00	9.58	6,700.57	9.56	35,741.93	50.95	235	15.46	<0.01	2,607.85	537.92	1.79

Terrestrial and aquatic cumulative effect indicators for the Dry Mixedwood Natural Subregion – historical (1981) time period

Dry Mixedwood Natural Subregion	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Mean (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of NSR	(ha)	% of NSR	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.23	0.00	0.00	2.02	70.80	0.57	—	—	—	—	—	—	13.88	0.28
Truck Trails and Rough	0.36	0.00	0.00	7.74	35.77	0.29	—	—	—	—	—	—	8.83	0.18
Cutlines, Snowmobile/ATV trails	1.14	0.92	0.00	8.89	88.42	0.71	—	—	—	—	—	—	34.08	0.70
Power Lines	0.04	0.00	0.00	1.89	23.46	0.19	—	—	—	—	—	—	8.20	0.17
Pipelines	0.04	0.00	0.00	1.99	8.82	0.07	—	—	—	—	—	—	6.16	0.13
Recreational Trails (e.g hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	6.20	0.05	—	—	—	—	—	—	5.54	0.11
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.26	0.00	—	—	—	—	—	—	0.19	0.00
Wellsites	—	—	—	—	26.44	0.21	—	—	—	—	—	—	6.32	0.13
Rural Residential/Cabins	—	—	—	—	51.90	0.42	—	—	—	—	—	—	11.23	0.23
Recreational Facilities	—	—	—	—	2.72	0.02	—	—	—	—	—	—	2.07	0.04
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	3,149.57	25.40	—	—	—	—	—	—	321.60	6.58
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.81	1.58	0.00	9.23	3,464.36	27.93	2,724.46	21.97	82	11.33	<0.01	386.21	418.10	8.55

Terrestrial and aquatic cumulative effect indicators for Township 64, Range 4, W4M – historical (1981) time period

Township 64, Range 4, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Mean (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.01	0.00	0.00	0.48	0.84	0.01	—	—	—	—	—	—	0.18	0.01
Truck Trails and Rough	0.43	0.00	0.00	9.54	13.32	0.23	—	—	—	—	—	—	2.97	0.20
Cutlines, Snowmobile/ATV trails	1.18	1.05	0.00	6.87	50.01	0.88	—	—	—	—	—	—	10.81	0.71
Power Lines	0.12	0.00	0.00	1.17	39.27	0.69	—	—	—	—	—	—	2.26	0.15
Pipelines	0.12	0.00	0.00	1.23	10.69	0.19	—	—	—	—	—	—	0.98	0.06
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	6.20	0.11	—	—	—	—	—	—	5.54	0.36
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	31.33	0.55	—	—	—	—	—	—	4.64	0.31
Rural Residential/Cabins	—	—	—	—	20.84	0.37	—	—	—	—	—	—	10.32	0.68
Recreational Facilities	—	—	—	—	2.72	0.05	—	—	—	—	—	—	2.07	0.14
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	6.77	0.12	—	—	—	—	—	—	2.77	0.18
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.85	1.38	0.00	11.05	181.99	3.20	3,005.99	52.66	16	56.71	1.21	965.07	42.54	2.80

Terrestrial and aquatic cumulative effect indicators for Township 64, Range 5, W4M – historical (1981) time period

Township 64, Range 5, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	**Mean (km/km^2)**	**Median (km/km^2)**	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	**Median Size (ha)**	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Secondary Roads	0.08	0.00	0.00	1.68	12.92	0.14	–	–	–	–	–	–	2.81	0.09
Truck Trails and Rough Roads	0.23	0.00	0.00	2.40	21.25	0.23	–	–	–	–	–	–	4.94	0.16
Cutlines, Snowmobile/ATV trails	1.45	1.42	0.00	5.35	102.21	1.11	–	–	–	–	–	–	27.49	0.88
Power Lines	0.04	0.00	0.00	1.00	16.11	0.17	–	–	–	–	–	–	7.80	0.25
Pipelines	0.05	0.00	0.00	1.22	7.00	0.08	–	–	–	–	–	–	5.66	0.18
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Communities	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Mines and Quarries	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Industrial Facilities	–	–	–	–	0.26	0.00	–	–	–	–	–	–	0.19	0.01
Wellsites	–	–	–	–	12.10	0.13	–	–	–	–	–	–	1.58	0.05
Rural Residential/Cabins	–	–	–	–	9.65	0.10	–	–	–	–	–	–	0.15	0.00
Recreational Facilities	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Borrow Pits	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Crop/Pasture Land	–	–	–	–	856.03	9.29	–	–	–	–	–	–	91.05	2.91
Cutblocks	–	–	–	–	0.00	0.00	–	–	–	–	–	–	0.00	0.00
Historical Footprint TOTAL	1.85	2.00	0.00	5.35	1,037.53	11.25	3,107.47	33.71	53	13.57	<0.01	958.70	141.67	4.53

Terrestrial and aquatic cumulative effect indicators for Township 64, Range 6, W4M – historical (1981) time period

Township 64, Range 6, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Mean (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.12	0.00	0.00	2.07	25.47	0.29	—	—	—	—	—	—	3.55	0.14
Truck Trails and Rough	0.30	0.00	0.00	2.61	25.83	0.29	—	—	—	—	—	—	3.58	0.14
Cutlines, Snowmobile/ATV trails	1.10	1.00	0.00	4.82	55.37	0.63	—	—	—	—	—	—	21.55	0.83
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	26.38	0.30	—	—	—	—	—	—	6.58	0.25
Rural Residential/Cabins	—	—	—	—	12.11	0.14	—	—	—	—	—	—	0.28	0.01
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	3,806.19	43.14	—	—	—	—	—	—	171.48	6.59
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.52	1.45	0.00	4.82	3,951.35	44.79	1,084.04	12.29	42	9.40	<0.01	182.91	207.02	7.96

Terrestrial and aquatic cumulative effect indicators for Township 64, Range 7, W4M – historical (1981) time period

Township 64, Range 7, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Mean (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.40	0.00	0.00	2.06	47.09	0.86	—	—	—	—	—	—	9.23	0.60
Truck Trails and Rough	0.13	0.00	0.00	1.60	6.68	0.12	—	—	—	—	—	—	0.84	0.05
Cutlines, Snowmobile/ATV trails	1.15	0.99	0.00	3.97	33.95	0.62	—	—	—	—	—	—	10.84	0.71
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	8.29	0.15	—	—	—	—	—	—	0.52	0.03
Rural Residential/Cabins	—	—	—	—	20.87	0.38	—	—	—	—	—	—	0.77	0.05
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	2,254.14	41.40	—	—	—	—	—	—	205.69	13.44
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.67	1.67	0.00	3.97	2,371.02	43.53	439.40	8.07	35	5.72	0.04	77.95	227.89	14.88

Terrestrial and aquatic cumulative effect indicators for Township 65, Range 4, W4M – historical (1981) time period

Township 65, Range 4, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Mean (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Truck Trails and Rough	0.23	0.00	0.00	2.07	15.37	0.23	—	—	—	—	—	—	2.90	0.10
Cutlines, Snowmobile/ATV trails	1.22	1.10	0.00	7.83	62.68	0.96	—	—	—	—	—	—	29.42	0.99
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	34.82	0.53	—	—	—	—	—	—	14.49	0.49
Rural Residential/Cabins	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.45	1.24	0.00	7.83	112.87	1.72	3,284.75	50.21	27	31.44	<0.01	618.43	46.81	1.58

Terrestrial and aquatic cumulative effect indicators for Township 65, Range 5, W4M – historical (1981) time period

Township 65, Range 5, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Mean (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.05	0.00	0.00	1.26	9.46	0.11	—	—	—	—	—	—	0.52	0.01
Truck Trails and Rough	0.06	0.00	0.00	1.90	4.10	0.05	—	—	—	—	—	—	1.34	0.03
Cutlines, Snowmobile/ATV trails	0.96	0.76	0.00	5.22	66.19	0.75	—	—	—	—	—	—	38.28	0.79
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	16.94	0.19	—	—	—	—	—	—	8.29	0.17
Rural Residential/Cabins	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	159.64	1.81	—	—	—	—	—	—	3.06	0.06
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.07	0.99	0.00	5.22	256.33	2.91	5,406.37	61.13	29	4.77	0.02	1,308.00	51.49	1.06

Terrestrial and aquatic cumulative effect indicators for Township 65, Range 6, W4M – historical (1981) time period

Township 65, Range 6, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Mean (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.09	0.00	0.00	1.67	16.64	0.18	—	—	—	—	—	—	4.03	0.10
Truck Trails and Rough	0.07	0.00	0.00	2.13	4.39	0.05	—	—	—	—	—	—	0.20	0.00
Cutlines, Snowmobile/ATV trails	0.66	0.31	0.00	3.02	40.93	0.45	—	—	—	—	—	—	14.35	0.34
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	9.51	0.10	—	—	—	—	—	—	3.12	0.07
Rural Residential/Cabins	—	—	—	—	0.94	0.01	—	—	—	—	—	—	0.94	0.02
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	1,423.12	15.61	—	—	—	—	—	—	66.91	1.60
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	0.82	0.61	0.00	3.07	1,496.53	16.40	4,845.13	53.14	23	10.05	<0.01	1,550.57	89.55	2.13

Terrestrial and aquatic cumulative effect indicators for Township 65, Range 7, W4M – historical (1981) time period

Township 65, Range 7, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Mean (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.07	0.00	0.00	1.14	8.62	0.16	—	—	—	—	—	—	0.03	0.00
Truck Trails and Rough	0.02	0.00	0.00	0.75	1.13	0.02	—	—	—	—	—	—	0.25	0.01
Cutlines, Snowmobile/ATV trails	0.97	1.01	0.00	6.37	37.22	0.71	—	—	—	—	—	—	10.50	0.54
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	1.21	0.02	—	—	—	—	—	—	1.20	0.06
Rural Residential/Cabins	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	29.40	0.56	—	—	—	—	—	—	10.06	0.52
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	345.13	6.55	—	—	—	—	—	—	4.94	0.25
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.05	1.06	0.00	6.37	422.71	8.02	2,935.62	55.75	19	42.57	0.04	717.47	26.98	1.38

Terrestrial and aquatic cumulative effect indicators for Township 66, Range 4, W4M – historical (1981) time period

Township 66, Range 4, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Mean (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Truck Trails and Rough	0.08	0.00	0.00	3.25	2.28	0.04	—	—	—	—	—	—	0.55	0.02
Cutlines, Snowmobile/ATV trails	1.06	1.00	0.00	5.11	42.59	0.74	—	—	—	—	—	—	21.12	0.72
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	12.10	0.21	—	—	—	—	—	—	2.40	0.08
Rural Residential/Cabins	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.15	1.00	0.00	5.78	56.97	0.99	3,803.97	66.27	15	75.03	0.07	705.56	24.07	0.82

Terrestrial and aquatic cumulative effect indicators for Township 66, Range 5, W4M – historical (1981) time period

Township 66, Range 5, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Mean (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.13	0.00	0.00	1.15	23.60	0.30	—	—	—	—	—	—	4.62	0.13
Truck Trails and Rough	0.06	0.00	0.00	1.86	2.76	0.03	—	—	—	—	—	—	0.61	0.02
Cutlines, Snowmobile/ATV trails	1.14	1.00	0.00	13.12	59.98	0.76	—	—	—	—	—	—	27.67	0.77
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	39.38	0.50	—	—	—	—	—	—	1.11	0.03
Wellsites	—	—	—	—	33.61	0.42	—	—	—	—	—	—	6.85	0.19
Rural Residential/Cabins	—	—	—	—	0.27	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	2.35	0.03	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.33	1.00	0.00	13.12	161.95	2.04	4,761.17	60.09	21	30.52	0.01	1,967.46	40.86	1.14

Terrestrial and aquatic cumulative effect indicators for Township 66, Range 6, W4M – historical (1981) time period

Township 66, Range 6, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km^2)				Total				Range (ha)			
Land Use Features	Mean (km/km^2)	Median (km/km^2)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Truck Trails and Rough	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutlines, Snowmobile/ATV trails	1.34	1.16	0.00	5.58	79.87	1.09	—	—	—	—	—	—	46.08	1.03
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	16.94	0.23	—	—	—	—	—	—	3.90	0.09
Rural Residential/Cabins	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	1.34	1.16	0.00	5.58	96.81	1.32	4,009.46	54.61	36	10.77	0.01	847.51	49.98	1.12

Terrestrial and aquatic cumulative effect indicators for Township 66, Range 7, W4M – historical (1981) time period

Township 66, Range 7, W4M	Landscape Indicator													
	Corridor Density				Land Use Footprint (Cleared Area)		Core Area						Riparian Footprint	
			Range (km/km²)				Total				Range (ha)			
Land Use Features	Mean (km/km²)	Median (km/km²)	min.	max.	(ha)	% of TWP	(ha)	% of TWP	No.	Median Size (ha)	min.	max.	(ha)	% of Riparian Zone
Paved Roads and Highways	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Secondary Roads	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Truck Trails and Rough	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutlines, Snowmobile/ATV trails	0.45	0.00	0.00	2.46	14.19	0.59	—	—	—	—	—	—	6.94	0.63
Power Lines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Trails (e.g. hiking)	0.00	0.00	0.00	0.00	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Communities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Mines and Quarries	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Industrial Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Wellsites	—	—	—	—	1.21	0.05	—	—	—	—	—	—	0.00	0.00
Rural Residential/Cabins	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Recreational Facilities	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Borrow Pits	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Crop/Pasture Land	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Cutblocks	—	—	—	—	0.00	0.00	—	—	—	—	—	—	0.00	0.00
Historical Footprint TOTAL	0.45	0.00	0.00	2.46	15.40	0.64	1,765.45	73.20	13	27.55	0.13	1,133.65	6.94	0.63